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ECL-258

THE MAGNETIC FUSION ENERGY ENGINEERING ACT OF 1980

An exploration of the key technical and political decisions affecting federal funding for the development of fusion technology. The role of technical experts in the decision process is highlighted.

Anthony Flores

Washington Internships for Students of Engineering (WISE) Program

ECL-258A

Educating Prospective Engineers for Public Policy

THE MAGNETIC FUSION ENERGY ENGINEERING ACT OF 1980

by

Anthony Flores[1]

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Prepared as part of the 1981 Washington Internships for Students of Engineering (WISE) Program under the supervision of Dr. Paul Craig[2], 1981 WISE Faculty-Member-in-Residence. Modified and edited by Barry Hyman.[3] This work was supported by NSF Grant SED 7918984. All opinions presented are those of the authors and do not in any way represent those of NSF, the author's institution, or other individuals or institutions referred to in the text.

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INTRODUCTION

Realization that humans need essentially inexhaustible energy sources is becoming increasingly apparent. Energy prices seemingly rise continually. We see this directly as increased energy costs and indirectly in the increased cost of all other services and processed goods that require energy. Coal and conventional nuclear fission resources can contribute in the near and mid-term, but the hope for supplying the bulk of mankind's energy needs rests in the development of inexhaustible energy sources. There are only four of these: solar, geothermal, fission-fuel breeders, and fusion.

While experts may disagree on which of these alternatives have more potential than others, each will probably be developed to the point where its potential across the full range of applications is known. This case examines the fusion option, with particular focus on aspects of the government's role in development of fusion's potential. In the remainder of this section, we provide a short introduction to fusion. The rest of this case is devoted to a history of the federal government's fusion program, with sprinklings of both technological and policy advances, culminating in a description of the events surrounding enactment by Congress of the Magnetic Energy Fusion Engineering Act of 1980. These latter parts of the case provide good insights into the manner in which the government receives advice from technical experts, and the influential role that a few key people can have on the legislative process.

The Fusion Process

When a gas consisting of light elements is raised to a high enough temperature and contained long enough, fusion reactions occur between nuclei as they collide. As the nuclei fuse, new elements are formed with a total mass less than the total mass of the original nuclei. Therefore, energy is released in proportion to Einstein's equation: $E = mc^2$ where E is the liberated energy, m is the lost mass, and c is the velocity of light. Of the many possible fusion reactions, the one involving deuterium and tritium, the two heavy isotopes of hydrogen, has the most favorable energy balance.

Deuterium can be economically seperated from water. It is therefore truly inexhaustible and readily available to all nations. Because tritium is beta radioactive with a half life of 12.26 years, it does not occur in nature in significant quantity. However, tritium is readily produced by neutron bombardment of lithium, a fairly abundant resource.

Deuterium-tritium (D-T) fusion requires that the reacting gas be contained at a temperature on the order of 10^8°K. At such temperatures, hydrogen nuclei are separated from their electrons. This 4th state of matter, consisting of free electrons and positive ions, is called a plasma.

In addition to a requirement for high temperature, plasma must be confined long enough, at sufficient density, for a significant number of reactions to occur. Otherwise, the total energy released from fusion will be less that the energy required to create the high temperature in the first place. This condition is usually expressed as the product of the particle density n, and the confinement time, τ. This product $n\tau$, must exceed approximately 10^{14} particle-sec/cm^3 while the plasma is being maintained at the required temperature.

The achievement of these temperature and confinement ($n\tau$) thresholds is known as the Lawson Criterion for scientific break-even. Even higher temperatures and greater confinement are required for actual ignition of the plasma so that the reactions are self-sustaining and no external heating is required.

Extremely strong magnets are used to confine the hot plasma and prevent it from coming in contact with the walls of the reactor. There are at present two major magnetic confinement concepts: the mirror and the torus. There are also other concepts that show promise in magnetic fusion, some of which combine the assets of both mirrors and torii. For the time being, the most advanced confinement scheme is the tokamak, a variation of the torus concept.

Inertial confinement is another method of confinement being pursued for commercial fusion. Presently, however, most inertia confinement work is done for military applications and the commercial applications program for inertial confinement is far behind the magnetic confinement program.

PART A: A BRIEF HISTORY OF THE FUSION PROGRAM

The U. S. Government's involvement with fusion began in 1951-52 as a classified program at three different federal laboratories with three different approaches. They were the Z-pinch at Los Alamos Scientific Laboratory, the Mirror at Lawrence Livermore Laboratory, and the Stellarator at Princeton Plasma Physics Laboratory. Although these concepts were different, they all relied on magnetic confinement.

Early Optimism Shaken

As the data from preliminary small-scale experiments were coming in during the mid 50's, researchers were increasingly optimistic about future development of the technology. The preliminary density and heating results looked favorable, and efforts were then directed towards achieving short-term technological advances with existing devices, rather than concentrating on building a stronger scientific data base. Researchers were estimating that feasibility of confinement could be demonstrated within ten years at the relatively modest cost of several million dollars.

But the bottom fell out in the late 50's and early 60's. Scientists began to realize that successes were illusory and based on incomplete analysis. Also, when the U.S., U.S.S.R., and U.K. agreed to declassify their fusion data, it was discovered that no one else was doing any better.

Once the fusion community realized its problems it returned to basic research in the 60's. During this period there were some moderate successes but things moved very slowly. Enthusiasm waned as more and more instabilities were identified and found capable of destroying confinement. It was a "dark age" for magnetic confinement fusion.

Signs of Progress

Meanwhile, in the early 1960's scientists realized that laser beams offered a medium for delivering large amounts of energy in very short periods of time. This realization prompted the U.S. Atomic Energy Commission (AEC) in 1963 to fund laser fusion research. Initial calculations showed need for a high-energy laser, so emphasis was placed on developing a glass laser at Lawrence Livermore Laboratory; later, work was also begun on a carbon dioxide (gas) laser at Los Alamos Scientific Laboratory.

In 1968, the Soviet Union had a fusion breakthrough. They had achieved spectacular results in confining plasma with a new type of toroidal magnetic confinement device, called tokamak. The U.S. quickly jumped on the tokamak bandwagon and phased out the stellarators by converting them to tokamaks. The Americans verified the Russian experimental results and international interest in magnetic fusion rose dramatically.

Shift in Management Strategy

At the same time, there were changes in management of fusion research strategy. Initially, fusion R & D strategy was the result of individual laboratory directors promoting their own projects. This continued until the late 60's when Amasa S. Bishop became the Washington director of the AEC fusion program. He set up a standing committee of government laboratory heads and outside physicists to oversee the program. Later, in the early 70's, when Robert L. Hirsch became the director of the Division of Fusion Energy within the AEC, strategy formulation moved even more from the laboratories to the Washington Office.

Dr. Hirsch's undergraduate degree is in Mechanical Engineering (University of Illinois, 1958) and his master's degree is in Nuclear Engineering (University of Michigan, 1959). He worked in various aspects of fission reactor research and development through mid-year 1960, when he decided to change his career direction and work in fusion power research and development. Accordingly, he returned to the University of Illinois and studied plasma physics, receiving his Ph.D. in 1964. From 1964 to 1968 he did experimental fusion plasma physics at the ITT Industiral Laboratories, and in 1968 he joined the Atomic Energy Commission as a staff physicist in the fusion program. In 1972 he was appointed director of the magnetic confinement fusion program.

Hirsch set ambitious goals for the fusion program and fast-paced schedules to meet those goals. His main objective was to get a commercial fusion reactor as soon as possible. Hirsch constantly considered political factors in advancing fusion, because he believed an adequate federal fusion budget had to be in the 100's of millions of dollars

annually, not in the 10's of millions, as it was at that time. He believed fusion scientists and engineers had to set and meet specified milestones that would represent progress in the eyes of all those who viewed the program, including the politicans who authorize the money.

As part of his program, Hirsch set a goal of scientific feasibility by 1980-82. To achieve this goal, it was proposed that a Tokamak Fusion Test Reactor (TFTR) be built to serve as a bridge between existing tokamaks and commerical reactor devices. It would also be the first tokamak to achieve scientific break-even, but this could be achieved only if it utilized deuterium tritium (D-T) for fuel.

D-T or not D-T

The scientific, political, and psychological arguments favoring the use of D-T fuel in TFTR are summarized below.

Scientific: Burning D-T would create new properties in the plasma. The very energetic helium nuclei produced by the fusion reaction would enter the plasma as a new component. Hirsch himself had used D-T in his work at ITT in the 60's. Also, other aspects of tokamak technology appeared to be well in hand with the exception of impurities control.

Political: Using ordinary hydrogen as the fuel used by other tokamaks could only lead to a simulation of "equivalent break-even". That was too esoteric a result to convince Congress to support a vigorous fusion program. An experiment that lead to actual power production would be needed to demonstrate the viability of fusion. The feasibility experiment should use real radioactive fuel to convincingly demonstrate the potential of fusion as a commercial source of energy.

Psychological: Many scientists active in the fusion field are engaged in theoretical physics research. In order to achieve a working commercial reactor they had to start thinking in terms of a practical energy generator. A D-T experiment might do just that.

The main arguments against use of radioactive D-T fuel had to do with technical complexity. While this approach was a welcome challenge to the engineers, this was the type of experiment phyicists abhorred. It would no longer be a simple, flexible, and quick route from conception to data. Tremendous shielding requirements and wall sputtering,

all caused by intense neutron fluxes from the radioactive reaction had to be accounted for. Because of inherent radiation, a very complex remote handling system would have to be developed. This would require a high degree of reliability once the D-T reaction was initiated.

In addition, impurities still plagued all operating tokamaks and would probably have more pronounced effects as temperatures increased. It was also believed that as the plasma was heated it would enter a collisionless regime and slip into "banana orbits" due to the magnetic field gradient between the inside and outside of the torus. These orbits could increase energy losses through diffusion and heat conduction, but these latter problems would be just as likely to occur whether radioactive fuel was used or not. The question was whether scientists could handle these problems in addition to those unique to a radioactive fuel.

Hirsch decided to go with the use of the D-T fuel. When viewed in light of the present data available the TFTR design seems quite conservative. In fact, it will have to be upgraded in several areas to maximize its usefulness. Its total cost is expected to be $314 million. Break-even is expected sometime after 1983 with the TFTR now nearing completion at Princeton.

President Carter De-emphasizes Fusion

With arrival of the Carter Administration in January 1977 centralization of fusion energy decision making continued. Unfortunately for the fusion program the Carter Administration's energy policy called for an emphasis on solar and conservation projects. When the Secretary of Energy noticed that the budget for fusion had grown rapidly in prior years, he asked for a review of the program. An Ad Hoc Experts Group chaired by Dr. John S. Foster of TRW, Inc. was created to conduct a review of the fusion energy program. This group recommended in June, 1978, that "Demonstration of scientific and technological feasibility should remain the near-term aim of the program. Its achievement should be a necessary, but not sufficient, step in the decision to proceed with the construction of an engineering prototype reactor." The group also observed that the program was moving along successfully, but should slow slightly to reduce program risk and allow alternatives to the tokamak to develop.

Although the fusion budget dropped in real dollars in the first Carter budgets (FY 78 & 79), the reduction might well have been much greater without the endorsement of the Foster Report.

In April 1979, during hearings for the FY 80 budget the House Science and Technology Committee learned about recent advances in fusion technology. The Administration, however, had chosen to limit the fusion program budget and the effect of the limitation was to push the target date for the first demonstration plant at least 10 years past the original target year of 2000.

To Congressman Mike McCormack, then Chairman of the Subcommittee on Energy Research and Production of the House Science and Technology Committee, this delay seemed totally inappropriate. Representative McCormack, one of the few scientists serving in Congress, had both a professional and political interest in supporting nuclear energy projects. Mr. McCormack received his B.S. and M.S. degrees in Chemistry from the University of Toledo and Washington State University, respectively, and spent twenty years as a research scientist at the Hanford nuclear energy laboratories near Richland, Washington. He is a member of both the American Nuclear Society and the American Chemical Society and served on the Board of Directors of the American Association for the Advancement of Science. After serving in the Washington State Legislature for a decade, he was elected to Congress from a district whose constituency is highly dependent on activities at Hanford for the health of the local economy.

Mr. McCormack's interest in, and advocacy for, fusion energy development went back to the early 1970's. Since that time, he and Bob Hirsch had worked closely in an unofficial partnership to advance the fusion cause. Thus, when the recent advances in fusion were juxtaposed against Carter's budget cuts for fusion, it seemed to McCormack that, although the operation was a success, the patient was still dying.

PART B: MIKE MCCORMACK TO THE RESCUE

Laying The Groundwork

In order to provide technical and industrial expert input to his subcommittee, Congressman McCormack established a Fusion Advisory Panel (FAP) chaired by Dr. Robert Hirsch, who had left government service in 1977 and was then with Exxon. That summer, FAP recommended the federal fusion program be accelerated to produce a demonstration plant by the year 1995. This, in turn, prompted McCormack to request that Undersecretary of Energy John Deutch draw up two accelerated plans that would lead to a demonstration plant on-line by 1995 and 2000. Deutch, in a Sept. 20 response to McCormack, provided an analysis of these two accelerated schedules along with a "base" pace of the current funding level with a demonstration in the year 2010. But in his letter Deutch restated the Carter administration position that the fusion program should not be accelerated. This exchange of correspondence between Hirsch, McCormack and Deutch is reproduced in Exhibit B-1.

In December 1979, the FAP was convened for a second time. During this meeting they reviewed the DOE's response to the subcomittee's request for accelerated schedules. Dr. Hirsch, FAP Chairman, appeared before the subcommittee on Dec. 11. Part of his testimony is reproduced as Exhibit B-2. Also appearing before the subcommittee on Dec. 11 was Mr. Edwin Kinter, Director of the Office of Fusion Energy in DOE. His prepared remarks and portions of the subsequent dialog between Mr. Kinter and Congressman McCormack are also reproduced in Exhibit B-2. Notice that the question of whether, and when, to build a fusion Engineering Test Facility (ETF) emerged as a focal point for differences between McCormack and the adminisistration.

Legislative Action

Congressman McCormack introduced H.R. 6308, The Fusion Energy Research, Development and Demonstration Act of 1980, on January 28, 1980. The stated purpose of McCormack's bill was "to provide for an accelerated program of research and development of magnetic fusion energy technologies leading to the construction and successful operation of a magnetic fusion demonstration plant in the United States before the end of the twentieth century to be carried out by the Department of Energy." Essentially what McCormack was saying was that if he couldn't persuade DOE to proceed

quickly with building the ETF, he would get Congress to pass a law requiring that the work get done.

After additional hearings and input from FAP on the ETF (Exhibit B-3), the Committee on Science and Technology reported a slightly modified version of H.R. 6308 to the floor of the House of Representatives. See Exhibit B-4 for the text of the modified bill. On August 25, 1980, the House passed the bill by a vote of 365 to 7.

In the meantime, in response to increased Congressional interest, DOE had charged its Energy Research Advisory Board (ERAB) with reviewing the magnetic fusion program. Three days after the House had approved McCormack's bill, the findings of ERAB's Fusion Review Panel were submitted to DOE by the panel's chairman, S.J. Buchsbaum. While it generally supported accelerating the fusion program, the Buchsbaum report proposed construction of a Fusion Engineering Device (FED), a somewhat more modest undertaking than the ETF proposed by McCormack. Some recommendations from this report are reproduced as Exhibit B-5.

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—Members of the Fusion Advisory Panel to Subcommittee on Energy Research and Production

Dr. Robert L. Hirsch, general manager, exploratory research, Exxon Research and Engineering Co.

Dr. Richard E. Balzhizer, vice president, Research and Development, Electric Power Research Institute.

Dr. Robert Conn, Chemical, Nuclear and Thermal Engineering Department, School of Engineering & Applied Sciences, University of California, Los Angeles.

Dr. Ersel Evans, vice president, Westinghouse Hanford Co.

Dr. T. Kenneth Fowler, associate director for CTR, University of California, Lawrence Livermore Laboratory.

Dr. Harold Furth, program director, Princeton Plasma Physics Laboratory, Princeton University.

Mr. Joseph G. Gavin, Jr., president, Grumman Corp.

Mr. Henry K. Hebeler, president, Boeing Aerospace Co.

Mr. John W. Landis, senior vice president, Stone & Webster Engineering Corp.

Dr. Tihiro Ohkawa, vice president and director, fusion division, General Atomic Co.

Mr. Robert I. Smith, chairman of the board, Public Service Electric and Gas Company.

Dr. Alvin W. Trivelpiece, corporate vice president, Science Applications, Inc.

Dr. Ronald C. Davidson, director, Plasma Fusion Center, Massachusetts Institute of Technology

Exhibit B-1

Exchange of Correspondence on Magnetic Fusion between the Fusion Advisory Panel, Congressman McCormack, and DOE Undersecretary Deutch.

Hon. Mike McCormack,
Chairman, Subcommittee on Energy Research and Production, House of Representatives, Washington, D.C.

Dear Mr. Chairman: The Fusion Advisory Panel of the Energy Research and Production Subcommittee of the House Science and Technology Committee met on July 10 and 11. At that time, the panel concentrated its attention on magnetic confinement fusion and briefly reviewed inertial confinement (laser) fusion. Even though you and your colleagues received an oral report from the panel on July 11, it was deemed important to provide you with a short letter documenting the results of our efforts. The following is provided on behalf of the panel and represents the views of the overwhelming majority of our group.

On the basis of the information presented to us as well as the background that the panel members have in fusion and related technologies, we have come to several important conclusions. First and foremost is that the fusion program has to date achieved a very substantial and impressive measure of success. The magnetic confinement program has reached, and in many cases surpassed, the goals publicly set forth in past years. Magnetic fusion research has consistently been on schedule and very close to cost, even during recent inflationary times. On this basis, we see the program to be not only viable, but unusually meritorious and a source of national pride.

Second, as evidenced by recent results from the Princeton Large Torus, the Alcator, the Impurities Studies Experiment, and Doublet III, we believe that the magnetic fusion energy program is without a doubt ready to proceed much more aggressively than presently projected by the DOE. A key element in an expanded program would be a billion dollar class experimental fusion power system. In our view, this step must be formally initiated in the near term, not only because of the country's urgent need for energy for the future but because a delay would substantially reduce the effectiveness of the ongoing program. We wholeheartedly believe that electric power from fusion should be attainable before the turn of the century, and we believe the total programmatic cost for an accelerated program will be lower than for the present stretched out schedule.

In view of these conclusions and based upon our deliberations, we recommend that the Subcommittee seriously investigate a more vigorous approach to practical fusion power. Specifically, we recommend that the Department of Energy be requested to prepare a program plan aimed at the goal of operating a demonstration fusion power plant by the year 1995. Such a plan should include a description of technical elements, costs, schedules, industrial involvement, etc. Once this plan is developed, a special hearing should be held to determine the credibility and desirability of such a program goal. We realize this to be an aggressive approach, but we believe that the recent successes in magnetic fusion research coupled with the energy needs of the nation justify an ambitious magnetic confinement fusion program.

My colleagues and I on the Fusion Advisory Panel hope that our efforts thus far have been useful to the Congress. We were impressed by the strong interest in fusion power evidenced by the large Congressional representation at the panel's sessions.

Sincerely,

Robert L. Hirsch,
Chairman, Fusion Advisory Panel.

LETTER FROM CONGRESSMAN McCORMACK TO DEPARTMENT OF ENERGY REQUESTING DOE TO PREPARE ADVANCED PACE PROGRAM PLANS

COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C., July 24, 1979.

Dr. JOHN M. DEUTCH,
U.S. Department of Energy,
Washington, D.C.

DEAR JOHN: As you are aware, the Subcommittee on Energy Research and Production spent several days last week in meetings with its newly formed Fusion Advisory Panel. I was pleased that you had an opportunity to have dinner with the Panel members and to sense the urgency the members of the Panel and I feel with regard to moving forward aggressively with the Magnetic Fusion Program.

The presentations made to the Panel and the Subcommittee by Mr. Kintner and Dr. Canavan of the Department of Energy were extremely helpful and informative. The facts they presented, along with the existing familiarity with the subject by the Panel members, led us to conclude that we must at once explore the possibility of substantially increasing the pace of the Magnetic Fusion Program; much faster than is apparently being contemplated by the Administration. The members of the Panel and I were indeed distressed to hear that the Administration's target date for getting a magnetic fusion electric generation demonstration facility on the line has slipped to the year 2015.

Accordingly, I would like to take this opportunity to formally request that the Department of Energy explore the details of a substantially more aggressive scenario for reaching our goal of commercial fusion electricity. Will you please prepare for the Subcommittee a detailed schedule, including all significant steps and the cost of each, for getting a magnetic fusion electric demonstration plant on the line by the year 1995; and a similar schedule, with details and costs, by the year 2000?

I should advise you that we are completely sincere about moving forward with such a program. I believe that the Congress is prepared to authorize and appropriate the extra funds necessary to accomplish this goal. I see no reason why the Subcommittee would not authorize 250 million more than the Administration's present plan for magnetic fusion for fiscal year 1981; and equivalently increased sums for the following fiscal years in order to have a demonstration plant on the line before the end of the century.

We consider the potential contribution of fusion electricity to our society to be of such great importance that it must not, under any circumstances, be limited by routine budgetary considerations.

May I hear from you soon on this matter?

Sincerely,

MIKE McCORMACK,
Chairman, Subcommittee on
Energy Research and Production.

Department of Energy
Washington, D.C. 20585

Honorable Mike McCormack
Chairman
Subcommittee on Energy Research
and Production
Committee on Science & Technology
House of Representatives
Washington, D. C. 20515

Dear Mike,

I have received your July 24 letter on fusion energy and have prepared, in the enclosures, answers to the questions you outlined.

You requested that we prepare a planning case for the magnetic fusion program resulting in a demonstration electric power plant on line in the year 2000 and another case with a plant on line in the year 1995. In our planning within the magnetic fusion energy program we have considered, with broad involvement of the fusion community, a wide range of program paces consistent with the Department's basic policy on fusion--which is to develop its highest potential. The objectives of the Department's strategy for implementing this policy are these: demonstration of scientific feasibility, development and maintenance of a broad technical base, development of several confinement concepts, and strengthening the program's engineering capability in preparation for the Engineering Test Facility (ETF).

An important milestone in the plans is a major assessment of fusion's full potential as an energy option. In this assessment, coming after the operation of ETF and before final commitment to the succeeding step, an evaluation would be made leading to a choice of advancing directly to the Demonstration Plant (DEMO), proceeding to an Engineering Prototype Reactor (EPR), or reverting to additional R&D. In the plans presented here, we have assumed the outcome of the evaluation will be to advance to the Demonstration Plant. We have prepared three sets of plans, or planning "cases", which differ in funding profiles and milestone dates. Two of the cases are in direct response to your letter and the third represents a pace for fusion development, predicated upon a maintenance of the current base funding, which is included so that your cases can be seen in context.

The first plan—identified as the 'Base 2010' plan in the enclosures--is defined by an essentially constant budget for the base program with a funding increment corresponding to the construction costs of the

Engineering Test Facility and the DEMO. This plan bases the start of ETF on the results from TFTR and MFTF (or possibly MFTF-B), and would result in a Demonstration Plant on line in 2010. The fusion assessment would be made in 2001. The current DOE planning is consistent with this case in the near term. After the ETF decision, the DOE plans cover the range between this Base 2010 case and more rapid paces; the choice of pace would depend upon the circumstances at that time.

The second plan--identified as House Science and Technology 2000--'HS&T 2000'--is based upon proceeding with the program at a pace determined principally by technical considerations rather than by funding limitations. This results in a Demonstration Plant on line in the year 2000--your first case. The fusion assessment would be made in 1992.

The third plan--identified as 'HS&T 1995'--is based upon conducting the development at a more rapid pace with funds provided as needed for early starts and overlap of succeeding facilities. This would result in a Demonstration Plant on line by the year 1995--your second case. The fusion assessment could then be made in 1990.

In the enclosures, the three cases are described more fully in terms of schedules and sequences of major facilities, budgets by major elements and major milestones. In addition to the descriptors used in the enclosures, we believe that the choice of pace involves other important judgmental factors that are not easily quantified. These factors deal both with the three cases presented and with the fusion option as a whole. With regard to the former--the relative merits of the three cases--there are issues of financial and programmatic risk, including specifically balancing the maintenance of program options with the maintenance of program momentum and issues of the applicable methods of discounting and calculating cost/benefit analyses. With regard to the latter--the relative merits of fusion as an energy option--there are issues of market needs, assessment of urgency and the state of the competing options.

Let me say in closing--as I discussed with you and the members of your Fusion Advisory Panel, July 10, 1979--that we differ over the appropriate pace for the fusion energy program. This difference is rooted in the complexities of our national energy situation and in particular our assessment of the qualitative factors mentioned above. Within these many considerations, we must make judgments about the relative emphasis to put on near term supply and conservation measures and development of longer-term energy supply possibilities. We believe we have made the correct budgetary decisions that will support the magnetic fusion energy program in a responsible way.

I trust this information will satisfy your inquiry. As I know you recognize, we have summarized a considerable amount of planning work in these enclosures; if you or your staff wish to discuss this supporting information in more detail, we would be pleased to do so.

Sincerely,

John M. Deutch
Under Secretary

5 Enclosures
Table I Tabular Summary of Cost and Schedule Characteristics
Figure 1 Graphical Summary of Schedules
Figure II Fuller Description of Program Plan
Table II Tabular Summary of Budget
Glossary of Terms

Enclosure 1

Table I

Tabular Summary of Cost and Schedule Characteristics
for
Three Base and HS&T Magnetic Fusion Energy Program Planning Cases
(Costs in FY 1981 Dollars)

Planning Case	ETF Start Date[a]	Fusion Assessment Date[b]	DEMO On-Line	Total Cost[c]	Initial Operational Capability[d]	Averaged Yearly Funding FY 82-84
Base 2010	1986	2001	2010[e]	\$14.3B	2023	\$400M
HS&T 2000	1983	1992	2000	\$11.9B	2011	\$585M
HS&T 1995	1982	1990	1995	\$12.1B	2003	\$870M

a. Title I engineering
b. Assessment of fusion's potential as an energy option--results in a decision either to advance to DEMO, proceed to an Engineering Prototype Reactor (EPR) or revert to further research.
c. Includes total yearly costs from FY 1981 through operation of fusion Demonstration Plant.
d. Initial Operational Capability - production of 0.1-0.2 Quads of energy by a second generation of power producing plant (PLANTS).
e. The 1978 DOE Policy for fusion used as an example a 2015 date for the DEMO on line. In this year's reevaluation of the strategy supporting the policy, the range is from 2010 to 2020. Using the same assumption in all three cases that the fusion assessment will result in an advance to DEMO, the 2010 data is shown.

STATEMENT OF
EDWIN E. KINTNER
DIRECTOR, OFFICE OF FUSION ENERGY
DEPARTMENT OF ENERGY
BEFORE THE
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
DECEMBER 11, 1979

MAGNETIC FUSION PROGRAM PLANNING AND PACE

It is a privilege to appear once more before this Subcommittee to speak to the Department of Energy's magnetic fusion program. You will recall that at my earlier appearance on July 10, my deputy and I described in some detail the technical basis for the program, its scientific and technological elements, and the technical progress in each element. Since we met, exactly five months ago, a number of events have occurred in our program; let me mention a few to bring you up to date before providing an overview of our program planning.

The Tandem Mirror Experiment (TMX) at Livermore became operational in this period. The early data looks encouraging enough that we are planning a full mirror program review over the next few months to provide the basis for a major decision on the future path for this principal alternative to tokamaks. Recently, we signed two agreements with the Japanese Government for significant U.S./G.O.J. cooperation in Doublet III research at La Jolla, and broader personnel exchange, joint planning, and a joint theory institute.

One of the most exciting events since July has been a general recognition on the part of the tokamak research community that a renewed effort toward better, simpler machines based on innovative advanced ideas is now appropriate. This continuing evolution in tokamaks is especially appropriate and necessary as the current tokamak embodiment appears capable of fulfilling the driver role in the Experimental Test Facility (ETF)--a role that could otherwise slow scientific creativity in the development of the tokamak concept.

On the negative side, we have also in this period analyzed what appears to be a common problem across our program: difficulties in bringing into reliable operation the larger, more powerful electrical equipment in our new experiments. We are working with all parties to strengthen our specification, design, and procurement of such equipment.

Each of these examples supports, in my view, the dynamic and unusual nature of the fusion program that leads to the special environment in which we must plan and manage this program.

Today I would like to describe some of the analysis and logic through which we have passed in planning the program, and then to describe in somewhat greater detail the three planning cases or program paces the Department provided in response to Congressman McCormack's letter of July 24, 1979.

There are several important factors affecting planning of the basic strategy for fusion development which makes it without any direct precedent. These considerations are shown on the first viewgraph. (Fig. 1) Fusion development cannot be evolutionary like the development of automobiles, airplanes, and electric utility plants because the required steps are simply too large. Moreover, the development of fission, although relatively recent and, it would seem, relatively close to the development of fusion in content, is not a good model because the scientific aspects of fission were, in the main, developed for weapons and other military programs. Moreover, the early power reactor experiments were only moderately expensive so that a number could be built and tested. You will recall that in addition to Pressurized Water and Boiling Water Reactors, Liquid Metal Cooled, Homogeneous, and Molten Salt concepts all were carried through the stage where small power reactors were built and operated.

Another characteristic of fusion development is that it does not now have military or semi-military urgency. Therefore, we cannot reduce risk or assure success by following to a conclusion a number of totally different parallel paths as was done in the Manhattan District; or a number of sequential steps, such as the Mercury and Apollo series in the space program.

Even so, the closest similarity probably is to the space program. (Fig. 2) There were two simultaneous thresholds for space travel: acceleration beyond the gravitational field of the Earth, and provision of a life-supporting environment in a void. Unless both of these requirements could be achieved simultaneously, man could not travel and function in outer space. In a sense there are two similar simultaneous thresholds for fusion. We must create and maintain a burning thermonuclear plasma, and then remove the heat energy from the burning plasma at a high enough temperature to convert it to useful power. If we do not do both of these simultaneously, we have not taken a truly meaningful next step toward useful fusion power. Therefore, in the fusion program, as in the space program, the next meaningful step is likely to be relatively large and take many years. (Fig. 3)

There was no facile answer as to the right course, so we have spent a great deal of time, over many years, carefully examining the alternative strategies and the internal logic of the fusion program to try to determine the best course of action within the special considerations of fusion just discussed.

The strategic concept of fusion development has gone through four and one-half stages. (Fig. 4) The first, in the early 1970's, visualized a Physics Test Reactor at 10 MW, an Experimental Power Reactor at 100 MW, and a Demonstration Power Plant at 1000 MW, each stage conveniently an order of magnitude larger than the one previous. These studies led to a decision to build the Tokamak Fusion Test Reactor (TFTR) and to study the Experimental Power Reactors (EPR) in the period

Exhibit B-2

Excerpts from December 1979 Hearings of House Science and Technology Committee on Magnetic Fusion.

1974-1976. The EPR studies led to the conclusion that EPR devices were premature --too large and too expensive. So that in the period 1976-1978, we considered something we called The Next Step (TNS), in which we opened the possible objectives more widely, extending from exploratory physics to the generation of power. These studies evolved into the general concept of an Engineering Test Facility (ETF).

But because the ETF would also be a large step, we attempted to find, from the entire fusion community, a shorter cut to energy production by conducting an Aggressive Experiment Competition among the various laboratories. These Aggressive Experiment studies indicated that there was no easy way, although they did lead to some significant conclusions, especially the potential for upgrading TFTR to significantly higher physics levels than it was originally intended to reach. So in 1978, we came to the conclusion that ETF was the best alternative as the next major step in fusion development.

To put this conclusion into somewhat broader perspective, it is useful to examine the status of magnetic fusion devlopment looking back from 1990. (Fig. 5) That date is chosen because it is the earliest date in our judgment, on which the first experimental results could be available from any large-scale step initiated in the near future.

By 1990, it will have been ten years or more since the following major confinement devices began operation:

- Princeton Large Torus (PLT)
- Poloidal Divertor Device (PDX)
- ALCATOR A
- ALCATOR C
- Impurity Studies Experiment (ISX-B)
- ZT-40 (Toroidal Reversed-Field "Z" Pinch)
- Tandem Mirror Experiment (TMX)
- Doublet-III (D-III)

The following major experimental devices will have operated five years or more:

- Tokamak Fusion Test Reactor (TFTR)
- Mirror Fusion Test Facility (MFTF)
- JT-60 (Japan's Tokamak)
- Joint European Tokamak (JET)

The following are additional devices under serious consideration which could be operating for up to five years:

- Mirror Fusion Test Facility-B (MFTF-B)
- Elmo Bumpy Torus-P (EBT-P)
- T-15 (Soviet tokamak device)
- ZEPHYR (Federal Republic of Germany Ignition Test Reactor)

By 1990, several fusion technology facilities will also have operated: (Fig. 6) Tritium Systems Test Assembly for about eight years; the Large Coil Project for eight years; and the Fusion Materials Irradiation Test for six years. I do not mean to indicate that the first two of these facilities will actually operate all that time, because I think that their useful life will be shorter than that, but only to indicate that they will have come into operation eight years earlier than 1990 and, therefore, their test results will have become available that early.

(Fig. 7) Looking backward from the perspective of 1990, as well as forward from the perspective of 1979, we have concluded that what is needed next is a decisive step toward developing and understanding the practicality of fusion—one which will create a programmatic challenge for all the engineering technologies, and which also will extend and challenge confinement physics at reactor levels. Institutionally, such a step would commence to create a strong industrial partnership with our already existing strong laboratory base. And because much of the developmental results from an ETF would be generic, that is, broadly useful for any confinement scheme—we can then explore the potential for other confinement schemes without a new ETF in each scheme.

An ETF (Fig. 7A) is one of the mechanisms that would provide pace and relevance to the entire fusion program, provide a test-bed to develop technologies for all fusion power reactor types, and demonstrate the technological feasibility of fusion, as we expect TFTR to demonstrate the scientific feasibility of fusion. It should also be capable of producing a small amount of electricity from fusion power for the first time.

Looking at this problem in yet another way, (Fig. 8) we can say that there are three fundamentally different directions which the fusion program might now take. One would be to move directly to the design and construction of a power producing reactor. We believe that, for the foreseeable future, such a step is premature, would involve a much higher near-term risk of failure, and would be significantly more costly than an ETF. In the opposite extreme, we could consider continuing, for the foreseeable future, with additional physics experimentation with such devices as a reactor to test burning plasmas and larger hydrogen and deuterium machines--none power producing. But in view of the significant number of physics devices already built or being built here and abroad, this course seems to be defocusing, splintering, and delaying to the program as a whole. I do not mean to imply that we will not need additional physics experimental devices, but that the need for these should derive from the design of an ETF or from the operation of present devices, rather than from a conscious intent to continue physics experimentation.

So between these two extreme strategies, the DOE's choice is one which is not as large, expensive and risky a step as a power producing reactor and yet moves consciously, deliberately and significantly towards making fusion useful.

But we have not yet precisely defined what an ETF is, although we are rapidly closing in on that judgment. Within the concept of an ETF there are three distinct possibilities. (Fig. 9) In the first case, we would have a driven machine in which the plasma does not <u>ignite</u>. It would be somewhat smaller and

Exhibit B-2, cont.

cheaper, but it wuld not push the confinement physics into power reactor regimes, and would require a significant continuous energy supply to operate it since it would be driven rather than ignited. The second case, our present ETF study, is ignited and adds the physics function and the engineering function beyond the TFTR.

There is a somewhat more advanced scheme which would propose to take this next major step in fusion on an international basis; i.e., the INTOR study being carried out through the International Atomic Energy Agency (IAEA). It would undoubtedly require increased time and additional cost over a project with similar objectives but conducted within one nation.

And now, having described to you some of the considerations associated with the next major step in fusion development, let me talk specifically to the three different paces which were discussed in Dr. Deutch's letter to Mr. McCormack dated September 20.

Before I do, let me make a few comments about the Department's policy for fusion. That policy is aimed at "developing the highest potential for fusion energy", not at its earliest development. The highest potential cannot be developed without an extensive technical base, both scientific and engineering. We must be confident that choices are based on a firm understanding of all significant technical alternatives. Further, questions of pace must consider the need for early or mid-term energy alternatives, balance financial and programmatic risks, consider market needs and the state of competing options. All of these considerations have been factored into the judgments of the Department regarding the balance and pace of the fusion program.

The first planning case (Fig. 10) provides for sequential scheduling of the major devices. It would arrive at a demonstration plant on line shortly after the year 2010. It assumes a flat level of funding for the base fusion program but provides incremental additions for an ETF commencing in 1986. This plan provides for completion of currently committed facilities on or near schedule, an upgraded MFTF (MFTF-B), the construction and operation of a Proof-of-Principle experiment based on the Elmo Bumpy Torus (EBT) concept, another advanced concept Proof-of-Principle later, and several small engineering technology test facilities It further assumes a choice of driver for the ETF in the mid-1980's based on experimental data from TFTR and MFTF.

Pace A assumes that three years are taken for the conceptual design of each major step and eight years for its detailed design and construction. It further assumes that each major facility is operated and its early output evaluated before the conceptual design of its successor is started.

Pace B (Fig. 11) is a more rapidly moving program which aims at achieving demonstration plant operation by the year 2000. It does so by projecting the conceptual design of each successive major facility to begin two years before the experimental operation of its predecessor. That experimental operation triggers the detailed design engineering of the successor facility. Case B also provides for two additional scientific facilities and a significantly upgraded technological effort on materials research so that the technical risk of moving more rapidly is reduced to something like the same level as in Case A. In this Case, the near-term budgets are significantly higher because the ETF design is begun in 1981.

In Pace C (Fig. 12) demonstration operation is achieved in 1995. This earlier date is made possible by beginning the detailed design of a facility before its predecessor has operated, relying on the early experimental operation from the predecessor facility to confirm, stop or modify if necessary before construction of the successor begins. Further, the design and construction period is reduced to five years, and $200 million is added to the base construction funds to provide for the additionol cost needed to expedite construction.

(Fig. 13) All three of these paces retain the basic internal logic of the DOE policy for fusion in (1) demonstration of scientific feasibility, (2) development of an engineering data base, (3) maintenance of a strong scientific and technological base, and (4) research into attractive alternate concepts.

I would like to reiterate that conscious actions have been taken to develop each of these cases intelligently as to technical risk and not simply to collapse or expand them; (Fig. 14) e.g., the number of new small facilities is higher from A to B and from B to C so as to provide additional ability to reduce risk with accelerated pace. This is reflected in the higher average yearly base program cost in the more accelerated case; it is also reflected in the additional construction cost allowed in the most rapid Case. (Fig. 15) The three paces provide a range of factors on which judgments can be based. These factors include integrated total program cost to Demonstration, which are about $14 billion in FY 81 dollars in the Case A and about $12 billion each in the two faster Cases B and C. Case A is more expensive largely due to the greater length of time on which the program depends on Federal funds before operation of the demonstration plant. We have not analyzed the character or cost of the program which might be carried out by industry following that point. The near-term costs in Case B are fifty percent higher than Case A, and the Case C near-term costs are doubled over Case A.

That is the end of my prepared testimony. I am ready to attempt answering any questions you may have.

<u>Exhibit B-2</u>, cont.

Dr. Hirsch. . . .

It was our view that electric power from fusion should be attainable before the turn of the century, and it seemed to us that the total programmatic cost for an accelerated program would be lower than for the present stretched-out schedule.

In view of these conclusions and based upon the panel's deliberations, we recommended that the subcommittee seriously investigate the more vigorous approach to the practical fusion power.

Specifically, the panel recommended that the Department of Energy be requested to prepare a program plan aimed at the goal of operating a demonstration fusion powerplant by the year 1995. Following up on the panel's report, Chairman McCormack asked the Department of Energy to submit three program plans for consideration by his subcommittee. These plans are characterized by their ultimate goal, the target dates for operation of the fusion electric demonstration plant. The three approaches are thus called the 1995 plan, the year 2000 plan, and the year 2010 plan.

It seems important to us for the subcommittee and the country to recognize two key aspects of the Department of Energy's reply to Chairman McCormack. The Department has affirmed that the goal of operating a fusion electric demonstration plant as early as 1995 is, indeed, credible. In other words, the country and the world could conceivably have fusion power before the turn of the century.

Second, the Department acknowledges that the direct cost to the Treasury to have fusion power sooner rather than later would be less in total dollars.

Yesterday, the panel heard presentations on the three program plans developed by the Department of Energy. These plans have clearly involved the consideration of many of the very complex technical matters relating to the development of magnetic fusion energy. Last night, the panel discussed what we had heard and formulated the following views and recommendations.

We continue to strongly believe that the present 2010 schedule for the demonstration of practical fusion power is unnecessarily and undesirably long. After looking at the details of the DOE planning scenarios and considering past experience in other high technology programs, we believe the engineering feasibility of fusion can be demonstrated before 1990 and that commercial fusion power can be demonstrated in the period 1995 to the year 2000.

It is also quite clear to us that these goals will require significantly increased funding. Indeed, if larger budgets are not forthcoming, the nation will be precluded from being able to exercise that fast track option. The magnetic fusion program is not technology limited, in the view of your advisory panel. The program is clearly funding limited.

While we recognize that this subcommittee and the full committee can take some actions to alter the course of funding, we believe that more initiative is required. Therefore, we strongly urge your committee, working through the Congress as a whole, to cooperate with the executive branch in attempting to establish a commitment necessary to accelerate and to maintain an intensified national magnetic fusion energy program.

The panel wishes to affirm the DOE goal of developing practical fusion power through a broad-based, many-pronged program. In our view, this approach is essential to achieving the best possible power system at the earliest reasonable date. As you know, the emphasis in the program has been on physics research, which required a great deal of sophisticated engineering. The panel feels that the time is right to begin a major engineering thrust. An engineering test facility is the proper focus for that effort. It is critically important that the engineering test facility not be considered as an end in itself. It must be a part of a broader program aimed at the ultimate goal of practical fusion power. An essential program element must be continuing scientific and technical innovation. Therefore, we strongly recommend that, along with the subcommittee's support for a test facility, you should encourage a vigorous program to improve the tokamak concept and to maintain healthy, competitive approaches.

We note the very useful international cooperation that has been characteristic of the magnetic fusion program in recent years. We believe that cooperation should continue in the future. However, those efforts should remain within bounds. The U.S. program should not, in our opinion, become significantly dependent on the efforts or the cooperation of foreign fusion programs.

In their presentations to us, the Department of Energy personnel made a point about their efforts to study the environmental and safety aspects of fusion. We applaud these efforts and feel that they should be extended to include public participation as well as consideration of possible institutional changes that may accompany the advent of fusion power.

In closing, your Fusion Advisory Panel wishes to leave you with two key points. We believe that this country now has a unique opportunity to develop fusion power as an extremely desirable and valuable new energy source which can meet the world's energy needs for essentially all time. What is needed to capture this opportunity is a national commitment to pursue it.

Thank you very much, Mr. Chairman.

Mr. McCormack. Thank you very much, Dr. Hirsch.

I have several questions. I want to give everyone else a chance to ask questions, too.

Dr. Hirsch. Yes, sir.

Mr. McCormack. My first question, of course, goes directly to the basic issue with which we are dealing here. That is, what is the realistic possibility of compressing the schedule for producing fusion power. The administration's present policy is to wait until 2015 or 2020. An aggressive plan would get the ETF on line by, let us say, 1987, and a fusion electric demonstration plant operating on line before the year 2000.

According to the Fusion Advisory Panel's first report [Congressional Record, Sept. 13, 1979] it should be cheaper to go with an accelerated program. Cheaper than staying with a stretched-out program.

My question is do you see any reason why this country could not adopt a much more aggressive policy, and could not compress the schedule, and could not establish the fusion electric program now? This would set the goal of getting a demonstration plant on line by the year 2000, just as we had an established goal in the Apollo program? Is there any reason why we could not do that, aside from administration policies?

Dr. Hirsch. I believe that Mr. Kintner might address this question also.

Mr. KINTNER. In my judgment, there are no reasons why we could not do that from a technical management point of view, Mr. Chairman.

Mr. McCORMACK. Could you use the other microphone, as that one is very weak? We cannot hear you too well, Mr. Kintner.

Mr. KINTNER. Is this better?

Mr. McCORMACK. That is better.

Mr. KINTNER. In my judgment, there's no reason why we could not do it from a technical management point of view. As I tried to indicate, however, there are considerations that are associated with the paces which have some implication with regard to your question. For example, pace A is a schedule in which there would be 3 years of conceptual design in each one of the major devices. That conceptual design begins only after its predecessor has operated and given physical information on which you could commence the design.

In Pace B, we have only 2 years of conceptual design. That 2 years takes place before the predecessor machine is operational, and the successful operation of that machine triggers the detailed design of the subsequent one. Now, these different timeframes and different sequences make a difference in the confidence in which one can make a decision to proceed on a major billion-dollar kind of machine. There are those considerations which I think have been used in a determination of the Department in reaching its basic policy with regard to the schedule. They are not purely administrative in the sense that they do have some indications with regard to the technical judgments for a major decision.

Mr. McCORMACK. Are you authorized to discuss any modification in the administration's position on this subject at this time with respect to the fiscal 1981 budget request, Mr. Kintner?

Mr. KINTNER. With respect to that?

Mr. McCORMACK. Yes.

Mr. KINTNER. No, sir. I am not authorized or unauthorized. I'm simply not prepared. I think it would not be appropriate to do so.

Mr. McCORMACK. Do you believe, as Dr. Hirsch said, that fusion can undoubtedly provide the human race with all kinds of energy; all that humanity will ever be able to use for all time? The development of fusion power will clearly be one of the most important events in the history of mankind. Do you see any reason why we should not compress the schedule? Do you see any reason why we must take our steps sequentially? Is it not realistic to try to take them somewhat in parallel and therefore not wait until we have every detail from one project before we start the next?

Mr. KINTNER. That's a very unfair question that you're asking. You know, without asking it—that is, I think you know my position—because anyone in the position as the program manager of something, and something I think everybody feels deeply committed to in terms of its implications—therefore, when we are in the position that we are, we want very much to proceed, absolutely. We believe we are dealing with the future of the race.

Mr. McCORMACK. I apologize for asking an unfair question. I should ask it of the President, the Secretary of Energy, and the Director of OMB. I won't put you under the gun.

Mr. KINTNER. Thank you.

Mr. McCORMACK. Let me ask one more question.

This has to do with supporting projects that you mentioned in your presentation yesterday and today that goes with getting a demonstration plant online by the year 2000. There are things such as the results of the handling facilities and so on. I would like to examine one of them as an example. That would be the tritium-handling facility. I really don't see the tritium-handling facility as essential to getting an engineering test facility on the line. We have tritium handling facilities at Savannah River at this time. If we chose to, we could do this in ETF, or we won't, depending on what our programs develop into. It really isn't essential, is it, to have a completed functional tritium-handling facility before we start ETF?

Mr. KINTNER. Not to start. Actually, the TSTA is on a schedule to provide information to fit into the design period for the ETF project. That's the basis on which it has been scheduled. We will need this information before we get too far into the design. We have enough information already from weapons programs and so forth, and from the actual design of the tritium system test assembly itself to allow us to proceed with the ETF.

Mr. McCORMACK. Would it be possible for you to review the entire program that you have now established as the essential program for a demonstration plant, review each component part of it to see which part is actually essential to get ETF online and which part would fit in later on?

Mr. KINTNER. Yes; it would.

Mr. McCORMACK. I made a note to myself as you were talking. You assume it is either desirable or essential to produce electricity with the ETF. I think this is a debatable question, certainly, where you have a machine which has not produced electricity. I would suggest that, if it is not essential to the success of the program to produce electricity, that we should seriously consider whether we really want to do it.

Mr. KINTNER. It would not need to be. I think the question is, as in the FFTF case, if we remove the heat at a high enough temperature that we can clearly see it could then be converted to useful power, then the ETF would have carried out its function. Once you've done that, it's easy enough to put a steam generator or a turbine generator on it and demonstrate fusion electricity. That is, from an engineering point of view as to the usefulness of the device, Mr. Chairman, as long as the systems and components testing is done, the generation of electricity would not be particularly important.

Mr. McCORMACK. It may be considered incidental to it, in some sense, is that correct, Mr. Kintner?

Mr. KINTNER. Yes.

Exhibit B-3

Recommendations of the Fusion Advisory Panel Regarding the Proposed Engineering Test Facility.

DRAFT STATEMENT AND RECOMMENDATIONS OF THE FUSION ADVISORY PANEL OF THE SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION OF THE HOUSE SCIENCE AND TECHNOLOGY COMMITTEE

MAY 20, 1980.

On May 19, 1980, the Fusion Advisory Panel met for the third time and heard a series of presentations on the engineering test facility proposed by the DOE magnetic fusion energy program. On the basis of these presentations as well as previous meetings, we formulated the following conclusions and recommendations.

First and foremost we wish to reaffirm all of what we have reported and recommended previously. Recall that we advised that in our view the magnetic fusion energy program had made major technological progress in recent years and was in a position to move into an engineering phase, aimed at commercialization before the year 2000. Further, we recommended that the focus for the engineering phase in the near term should be a billion dollar class engineering test facility, supported by continuing, strong, broad-based research programs.

We are pleased to note that the Atomic Industrial Forum has conducted an independent fusion study, which it finished in January, and the AIF reached conclusions very similar to those of this panel.

Most important, as a result of this panel's past findings and recommendations and Mr. McCormack's leadership in attempting to stimulate a national commitment to fusion development, DOE set up a special high-level fusion study group earlier this year. That panel recently provided a verbal report to the DOE Energy Research Advisory Board. We are happy to report that that DOE committee appears to have arrived at the same general conclusions reached by this panel.

Recently, the President responded to Mr. McCormack's proposal for a national commitment to fusion development with a positive but qualified letter. The President's qualifier was associated with his need for a final report from his special DOE Fusion Study Panel. Because of the positive preliminary report from that panel, there is hope that the White House will soon join the House Science and Technology Committee in supporting an accelerated fusion development program.

It is unfortunate that positive technological results, positive panel reviews, and opportunity for agressive action have all converged at a time when it is nearly impossible for the government to generate any new initiatives.

Turning to the engineering test facility (ETF), recall that it is to be a major new fusion facility, which is proposed to be the focus of an expanded engineering thrust aimed at a fusion commercial demonstration before the year 2000. ETF studies have been underway for about 5 years, and total national and international funds expended on studies of ETF or ETF-like systems is close to $15 million. On this basis there is a reasonably good definition of the envelope of what an ETF can do and what it might cost.

The panel notes the substantial progress that has been made by the ETF Design Center in the definition of machine parameters and the development of practical engineering design. A presentation on the INTOR project—a joint American, Soviet, Japanese, and European study aimed at an international version of an ETF design—impressed our panel, particularly in regard to the convergence of the machine parameter range that has been identified by the various national participants. The marked consistency of these international findings attests to the maturity and realism of the magnetic fusion energy field.

Agreement on a set of concrete ETF project objectives appears to be less well established. The ETF mission statement, as contained in the May 19 presentations, is not sufficiently explicit, while the INTOR mission statement seems to place too much emphasis on the aspect of long-term materials testing.

The panel believes that a specific, quantitative statement of the ETF mission is both possible and desirable, and recommends that the committee invite the DOE to provide such a statement.

As we have just stated, there is close agreement between the baseline parameters developed for the U.S. ETF and those developed in overseas fusion programs. These parameters form the basis for conceptual design studies underway at the U.S. design center, Oak Ridge. These activities involve university, laboratory, and industrial participation.

Plans for carrying the ETF beyond the conceptual design phase are being considered by DOE. On May 19, our panel was presented with three preliminary management plans. In the panel's opinion, none of those plans appears adequate to meet the full needs for the management of a program of the scope of the ETF.

Therefore, the panel sees the need for further consideration of the organizational structure required for the design and fabrication of

the ETF. The management approach adopted must ensure the following:

Engineering and operational requirements embodied in the conceptual design are confidently achievable.

Responsibility for the design and construction phases is placed in the hands of an organization or consortium that is experienced in the management and operational aspects associated with the construction of facilities of similar magnitude and complexity.

Close involvement continues between persons representing the universities, laboratories, and industrial contractors.

Adherence is maintained to the design objectives and schedules.

Above all, the organizational structure must permit an aggressive approach to project definition, construction, and completion.

The panel therefore recommends to the House Science and Technology Committee that it request the DOE to conduct an in-depth study of options for managing the ETF program. This study should include major inputs from the fusion community and from qualified industrial organizations.

The panel commends the excellent technical progress made by the INTOR study group towards the definition, on a worldwide basis, of the characteristics of the next major fusion facility. The U.S. effort in this area has been characterized by high technical quality and broad input from the fusion community. We recommend continued, strong U.S. participation in the INTOR studies, together with an increasing involvement of the U.S. INTOR participants in the ETF design activities. We believe that a separate U.S. INTOR study activity that interfaces effectively with the ETF design center will significantly benefit the ETF project as well as the INTOR design. While there are important technical benefits from the INTOR studies, we believe that the highest priority within the U.S. program should be to proceed expeditiously with the design, construction, and operation of a U.S.-based engineering test facility.

In conclusion, the Fusion Advisory Panel reaffirms its previous position:

There has been very significant recent technological progress in fusion research.

The time is now for an engineering thrust centering on an ETF.

This panel supports the present DOE balanced research and development program.

This panel also believes that fusion could be made commercial before 2000 if a national commitment is made soon.

With respect to specific action items, the Fusion Advisory Panel recommends that the House Science and Technology Committee make the following requests of the Department of Energy:

That DOE provide a clear, concise, and brief statement of the purposes of the engineering test facility.

That DOE immediately perform an in-depth study of organizational options for managing the ETF project and that that study include major inputs from the existing fusion community and very importantly, from qualified industrial organizations.

The panel continues to believe that the fusion program is a major source of national pride and the end result—practical fusion power—is likely one of the greater goods that most of us will ever be associated with. The panel is deeply concerned that recent budgetary actions will severely damage the cohesion and momentum that presently exists in the U.S. magnetic fusion energy program. If this happens, it will severely hamper the development of fusion power and it could seriously endanger what is likely to be the world's best long term energy option.

The primary problems facing expeditious development of fusion power are no longer technological; they are institutional.

That means that the development of fusion power is now primarily in the hands of the Congress and the President, not in the hands of the technologists.

The Fusion Advisory Panel wishes you well in your discharging of your responsibilities.

Exhibit B-3. cont.

ECL-258B

Calendar No. 681

96TH CONGRESS
2D SESSION

H. R. 6308

[Report No. 96–1096]

To provide for an accelerated program of research and development of magnetic fusion energy technologies leading to the construction and successful operation of a magnetic fusion demonstration plant in the United States before the end of the twentieth century to be carried out by the Department of Energy.

IN THE HOUSE OF REPRESENTATIVES

JANUARY 28, 1980

Mr. McCORMACK (for himself, Mr. FUQUA, Mr. WYDLER, Mr. ROE, Mr. WINN Mr. GOLDWATER, Mr. BROWN of California, Mr. FISH, Mr. SCHEUER, Mr. LUJAN, Mr. HOLLENBECK, Mr. DORNAN, Mr. LLOYD, Mr. WALKER, Mr. AMBRO, Mr. FORSYTHE, Mrs. BOUQUARD, Mr. KRAMER, Mr. BLANCHARD, Mr. CARNEY, Mr. WALGREN, Mr. FLIPPO, Mr. ROTH, Mr. GLICKMAN, Mr. RITTER, Mr. GORE, Mr. WATKINS, Mr. YOUNG of Missouri, Mr. WHITE, Mr. VOLKMER, Mr. PEASE, Mr. MAVROULES, Mr. ANTHONY, Mr. LUNDINE and Mr. ERTEL) introduced the following bill; which was referred to the Committee on Science and Technology

Additional sponsors: Mr. ALEXANDER, Mr. ASHLEY, Mr. ANDERSON of California, Mr. AuCOIN, Mr. BADHAM, Mr. BAILEY, Mr. BEDELL, Mrs. BOGGS, Mr. BREAUX, Mr. BROWN of Ohio, Mr. BROYHILL, Mr. BURGENER, Mrs. BYRON, Mr. CARTER, Mr. CHAPPELL, Mr. CHENEY, Mr. CLAUSEN, Mr. CLEVELAND, Mr. CLINGER, Mr. COELHO, Mr. CORCORAN, Mr. COTTER, Mr. COURTER, Mr. DANIELSON, Mr. DANNEMEYER, Mr. DAVIS of Michigan, Mr. DERWINSKI, Mr. DICKS, Mr. DOUGHERTY, Mr. DOWNEY, Mr. DRINAN, Mr. DUNCAN of Tennessee, Mr. DUNCAN of Oregon, Mr. EDWARDS of Oklahoma, Mr. ERDAHL, Mr. EVANS of Georgia, Mr. FASCELL, Mr. FAZIO, Mrs. FENWICK, Mr. FINDLEY, Mr. FOLEY, Mr. GIBBONS, Mr. GILMAN, Mr. GOODLING, Mr. GRAMM, Mr. HANCE, Mr. HANSEN, Mr. HAWKINS, Mr. HEFTEL, Mr. HUGHES, Mr. ICHORD, Mr. JONES of Tennessee, Mr. JONES of Oklahoma, Mr. KASTENMEIR, Mr. KINDNESS, Mr. LAFALCE, Mr. LEACH of Louisiana, Mr. LEATH of Texas, Mr. LEWIS, Mr. LOWRY, Mr. MADIGAN, Mr. MATHIS, Mr. MAZZOLI, Mr. McCLORY, Mr. McCLOSKEY, Mr. McDADE, Mr McKAY, Mr. MICHEL, Mr. MILLER of Ohio, Mr. MILLER of California, Mr. MINETA, Mr. MINISH, Mr. MITCHELL of New York, Mr. MOORHEAD of California, Mr. MURPHY of Illinois, Mr. MURTHA, Mr. MYERS of Indiana, Mr. NEAL, Mr. OTTINGER, Mr. PASHAYAN, Mr. PATTEN, Mr. PEPPER, Mr. PETRI, Mr. PICKLE, Mr. PORTER, Mr. PREYER, Mr. PRICE, Mr. PRITCHARD, Mr. PURSELL, Mr. REUSS, Mr. RHODES, Mr. RICHMOND, Mr. RINALDO, Mr. ROSTENKOWSKI, Mr. ROUSSELOT, Mr. RUDD, Mr. SEIBERLING, Mr. SHUMWAY, Mr. SIMON, Mr. SMITH of Iowa, Mrs. SPELLMAN, Mr. SPENCE, Mr. STANGELAND, Mr. STARK, Mr. STRATTON, Mr. STUDDS, Mr. STUMP, Mr. SWIFT, Mr. SYMMS, Mr. TRAXLER, Mr. ULLMAN, Mr. WHITEHURST, Mr. CHARLES WILSON of Texas, Mr. WRIGHT, Mr. WYATT, Mr. WYLIE, Mr. YOUNG of Alaska, Mr. ZABLOCKI, Mr. ABDNOR, Mr. BUCHANAN, Mr. MARKS, Mr. MARRIOTT, Mr. STACK, Mr. SENSENBRENNER, and Mr. BAFALIS.

JUNE 17, 1980

Reported with amendments, committed to the Committee of the Whole House on the State of the Union, and ordered to be printed

[Omit the part struck through and insert the part printed in italic]

A BILL

To provide for an accelerated program of research and development of magnetic fusion energy technologies leading to the construction and successful operation of a magnetic fusion demonstration plant in the United States before the end of the twentieth century to be carried out by the Department of Energy.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Fusion Energy Research, Development, and Demonstration Act of 1980".

FINDINGS AND POLICY

SEC. 2. (a) The Congress hereby finds that—

Exhibit B-4

Congressman McCormack's Bill as Approved by

(1) the United States of America continues to be dependent on imported oil, and is faced with a finite and diminishing resource base of native fossil fuels;

(2) the current imbalance between supply and demand for fuels and energy in the United States is likely to grow each year for many years, aggravating an energy crisis and threatening the economic strength and national security of the Nation;

(3) the energy crisis can only be solved by firm and decisive action by the Federal Government to conserve energy consumption in every realistic manner and to develop as quickly as possible a diversified and pluralistic national energy production capability;

(4) it is the proper and appropriate role of the Federal Government to undertake research, development, and demonstration programs in fusion energy technologies;

(5) fusion is the process by which the Sun makes its energy, and every nation of our world possesses in the oceans and waters of our planet an easily accessible and inexhaustible supply of fuel for fusion energy which cannot be embargoed, is inexpensively recoverable, and is usable with minimal environmental impact;

(6) the early demonstration of the feasibility of using magnetic fusion energy systems for the generation of electricity and the production of heat, hydrogen, and other synthetic fuels will initiate a new era of energy abundance for all mankind forever;

(7) the widespread use of fusion energy systems to supplement and eventually replace conventional methods for the generation of electricity will help provide energy independence for all nations of the world;

(8) the spectacular successes encountered in magnetic fusion energy research since mid-1978 provide fusion scientists throughout the world with the confidence that the time has come to move aggressively into the engineering phase of fusion development; and that the conditions required for scientific breakeven can be obtained in devices now under construction;

(9) the early development and export of fusion energy systems, consistent with the established preeminence of the United States in the field of high technology products, will improve the economic posture of the United States, and ultimately reduce the pressures for international strife by providing access to energy abundance for all nations;

(10) innovation and creativity in the development of fusion energy components and systems can be fostered through continued research of alternate concepts which show promising potential; and

(11) it is contemplated that the programs established by this Act will require the expenditure of approximately $20,000,000,000 during the next twenty years.

(b) It is therefore declared to be the policy of the United States and the purpose of this Act to establish an aggressive research, development, and demonstration program involving magnetic fusion energy systems. Further, it is declared to be the policy of the United States and the purpose of this Act that the objectives of this research, development, and demonstration program are—

(1) to proceed immediately with all work necessary to construct and operate a fusion engineering test facility by calendar year ~~1986~~ *1987*;

(2) to follow the operation of the fusion engineering test facility with all steps necessary to construct and successfully operate a magnetic fusion demonstration facility before the end of this century;

(3) to maintain, and where appropriate expand, the base programs for fusion energy research, and the development and testing of appropriate alternative confinement technologies;

(4) to maintain a strong research and development program in advanced fusion fuels; and

(5) to take appropriate measures to ensure the maintenance of an uninterrupted source of scientific and engineering talent from the Nation's colleges and universities in support of the magnetic fusion energy effort.

DEFINITIONS

SEC. 3. For purposes of this Act—

(1) a "fusion energy system" is a system of components which uses magnetic fields and appropriate monitoring and control systems to contain a hot, highly ionized gas (called a plasma) for the purpose of creating a controlled environment in which a fusion reaction can proceed, and which may include additional components such as energy storage and conversion devices, and systems to generate electricity or produce hydrogen and other synthetic fuels;

(2) the term "magnetic fusion energy system" may be used interchangeably with the term "fusion energy system";

(3) "fusion" refers to the process whereby two very light nuclei (for example, deuterium and tritium) are forced together, forming a compound nucleus, which subsequently separates into constituents which are different from the original colliding nuclei, with an accompanying energy release;

(4) the term "fusion engineering test facility" (FETF) refers to a fusion energy system designed to achieve net energy production; and may involve any or all of the generic engineering systems necessary for the construction of a demonstration plant;

(5) the term "fusion demonstration plant" (FDP) refers to a full-scale prototype production plant designed to demonstrate the safety, reliability, duty factors, and maintenance standards of a fusion energy system, including the generation of electricity or the production of synthetic fuels;

(6) the term "advanced fusion fuels" refers to fuels which will undergo a fusion reaction, other than that involving deuterium with tritium;

(7) "scientific breakeven" refers to the condition existing when sufficient fusion reactions are occurring to produce as much power as is consumed in creating the conditions for the fusion reactions to occur;

(8) "facility" means any building complex, or other device constructively employing fusion systems; and

(9) "Secretary" means the Secretary of Energy.

RESEARCH, DEVELOPMENT, AND DEMONSTRATION OF MAGNETIC FUSION ENERGY SYSTEMS

SEC. 4. (a) The Secretary is directed to establish immediately and carry forth such research, development, and demonstration programs, projects, or activities as may be necessary to meet the objectives of this Act as set forth in section 2(b). As a part of any such program, project, or activity, the Secretary shall—

(1) conduct and promote the coordination and acceleration of research development, and demonstration programs relating to magnetic fusion energy systems and components thereof;

(2) seek support from and encourage cooperative efforts with the United States private sector, and with other governments in carrying out the purposes of this Act;

(3) study the potential of using fusion energy systems for the production of hydrogen and other synthetic fuels, and for other nonelectric applications; and

(4) investigate the potential of using fusion power for the electrification of all or part of domestic ground transportation systems.

DISSEMINATION OF INFORMATION AND OTHER ACTIVITIES TO EDUCATE THE PUBLIC ON THE USE OF FUSION ENERGY TECHNOLOGIES

SEC. 5. The Secretary shall take all possible steps to assure that full and complete information with respect to the potential benefits of fusion energy, and the status and progress of fusion research, development, and demonstration is made available to Federal, State, and local authorities, relevant segments of the economy, the scientific and technical community, and the public at large, both during and after the close of the programs under this Act, with the objective of promoting and facilitating to the maximum extent feasible the early and widespread knowledge of the practical uses of fusion energy throughout the United States.

AUTHORIZATION OF APPROPRIATIONS

~~SEC. 6. There is hereby authorized to be appropriated to the Secretary, for the fiscal year ending September 30, 1981, $500,000,000, inclusive of any funds otherwise authorized to the Secretary for the purpose of research, development, and demonstration of magnetic fusion energy technologies, and for each succeeding fiscal year such sums as may hereafter be provided in annual authorization Acts.~~

"SEC. 6. There is authorized to be appropriated to the Secretary to carry out this Act (a) for the fiscal year ending September 30, 1981, $434,500,000, reduced by such sums as may be authorized for the same purposes in any Department of Energy fiscal year 1981 annual authorization Act, and (b) for subsequent fiscal years, such sums as may be authorized by legislation hereafter enacted."

Report on the Department of Energy Magnetic Fusion Program

PREPARED BY THE FUSION REVIEW PANEL OF THE ENERGY RESEARCH ADVISORY BOARD, AUGUST 1980

DEPARTMENT OF ENERGY,
Washington, D.C., August 28, 1980.

Hon. CHARLES W. DUNCAN,
Secretary of Energy,
Department of Energy,
Washington, D.C.

DEAR MR. SECRETARY: I am pleased to transmit on behalf of the Energy Research Advisory Board (ERAB) the report of its Fusion Review Panel. The Panel was organized in response to the request by the Director of Energy Research, dated February 8, 1980, to "undertake a review of the Department of Energy's (DOE) Magnetic Fusion Program." The report was reviewed and endorsed by ERAB at its meeting on August 19, 1980.

The report was made available to the public on 23 June in its draft form. Some three dozen extensive comments were received by the Board. The Board is satisfied that important issues raised by these comments were considered by the Panel and are treated in the report. We accepted several changes in the draft to clarify meaning.

Sincerely,

S. J. BUCHSBAUM,
Chairman, Energy Research Advisory Board.

Fusion Review Panel of the Energy Research Advisory Board

MEMBERS

S. J. Buchsbaum * (Chairman), executive vice president—customer systems, Bell Laboratories.

R. W. Conn, professor, School of Engineering and Applied Science, University of California, Los Angeles.

J. C. Fletcher *, vice chairman Burroughs Corp.

J. S. Foster, Jr.*, vice president—science and technology, TRW, Inc.

E. G. Fubini*, head, E. G. Fubini Consultants, Ltd.

M. L. Goldberger, president, California Institute of Technology.

R. W. Gould, chairman, Division of Engineering and Applied Science, California Institute of Technology.

W. K. H. Panofsky, director, Stanford Linear Accelerator Center.

M. N. Rosenbluth, professor, Institute for Advanced Study.

T. Johnson (Executive Secretary) U.S. Military Academy.

L. H. Roddis, a member of ERAB, joined the Panel as a consultant midway through the Panel's work.

T. B. Cochran, a member of ERAB, attended almost all the meetings of the Panel and participated in its activities.

* Member of ERAB.

I. Introduction

In February 1980, Dr. Edward A. Frieman, Director of Energy Research, requested that the Energy Research Advisory Board (ERAB) review the Department of Energy (DOE) Magnetic Fusion Program. (See Appendix A.) Of particular concern to the DOE is the judicious choice of the next major steps to be taken in proceeding from the current generation of experimental devices toward demonstration of economic power production from fusion. Of equal concern is the overall soundness of the DOE Magnetic Fusion Program: Its space, scope, and funding profiles.

This report is in response to Dr. Frieman's request. The present review follows a similar ad hoc DOE review of the fusion program that was carried out two years ago under the chairmanship of J. S. Foster, Jr., a member of the present Review Panel. The Foster report stimulated the DOE to enunciate a comprehensive policy for the fusion program. Rapid scientific progress since the writing of the Foster report has made the present review desirable.

To carry out the review, the ERAB appointed an ad hoc Fusion Review Panel. The Panel heard extensive presentations from Mr. Edwin E. Kintner, the Associate Director for Fusion, Office of Energy Research (OER), and his staff, and from numerous scientists and engineers in the program. The Panel spent eleven days in plenary sessions in Washington, at the Princeton Plasma Physics Laboratory (PPPL) and at the Lawrence Livermore National Laboratory (LLNL). Members of the Panel visited the Massachusetts Institute of Technology (MIT), the Oak Ridge National Laboratory (ORNL), the Los Alamos National Scientific Laboratory (LANSL) and General Atomic (GA). The Panel also received testimony from members of the public. (See Appendix B.)

The DOE Magnetic Fusion Program is large: In fiscal year 1980 some \$355M will be expended; in fiscal year 1981 nearly \$400M is included in the President's budget. (There is, in addition, some private funding, but this is not more than a few percent of what the Government spends.) The Panel is pleased to record its view that the taxpayers are receiving their monies' worth. The program is being well managed and is conducted by a cadre of dedicated, capable, and hard-working scientists and engineers. As we document in the body of the report, recent progress in plasma confinement is impressive. While the U.S. program represents only about a third of the worldwide effort in magnetic fusion, the United States has become its unquestioned leader. As a result of this progress, the United States is now ready to embark on the next step toward the goal of achieving economic fusion power: Exploration of the engineering feasibility of fusion.

The engineering program should augment the continuing basic work in fusion research and related technology. Such work is indispensable to the success of the fusion program.

The engineering program that the Panel envisages is a long and a difficult one. It will require the expenditure of significant additional funds; a doubling in the size of the present program (in constant dollars) in five to seven years must be expected.

Exhibit E-5
Report of the Fusion Review Panel of the Energy

the overall balance of DOE programs. This next step in the fusion program is both sound and timely. The U.S. should determine as soon as is programmatically feasible whether or not fusion is a viable option, that is, whether or not fusion reactors can compete favorably with alternate energy sources from economic, environmental, and safety standpoints. Such knowledge would have a profound influence on U.S. energy policy.

This report has four sections and five appendices. Section II is the Executive Summary. In Section III, we discuss the status of the fusion program. Section IV contains our conclusions and recommendations. A glossary of abbreviations and technical terms appears in Appendix C.

II. Executive Summary

Recent progress in plasma confinement justifies confidence that demonstration of scientific feasibility of magnetic fusion, that is, energy breakeven, is near. Such demonstration should take place in at least one of the devices presently under construction. There is also confidence, shared by the Panel, that a device containing a burning, even an ignited, plasma can be built and operated successfully.[1]

However, the state of knowledge is not adequate to determine an optimal configuration of plasma and magnetic field for a working reactor. Nor can we be sure today that a safe, environmentally acceptable economically attractive fusion reactor can be built and operated.

These conclusions lead the Panel to the following recommendations:

1. The magnetic fusion program can, and should, embark on the next logical phase toward its goal of achieving economic feasibility of magnetic fusion. To this end a broad program of engineering experimentation and analysis should be undertaken under the aegis of a Center for Fusion Engineering (CFE).

A key element of the program should be a device containing a burning plasma, and incorporating in its construction those technological features which can serve as a focus for the development of future reactor technology. Some of the objectives of the recently proposed Engineering Test Facility (ETF)—in particular, the level of neutron flux and duty cycle, as well as the role envisioned for the ETF on the road to commercialization of fusion—are inappropriate at this stage of fusion development. Rather, the program we advocate should center around a more modest, Tokamak-based Fusion Engineering Device (FED) which should have the following goals:

Provide a burning, perhaps even an ignited, plasma;

Provide a focus for developing and testing reactor-relevant technologies and components;

Explore and firmly delineate problems of operator and public safety.

The device should be in operation within ten years and cost not more than about one billion of 1980 dollars. The last two goals necessarily require certain limitations in other objectives; the extent of such limitations should emerge during the design phase of the device. Still, the device we envision will require a large, complex undertaking. A single-line management approach is necessary to help assure the success of such a large design and construction project supporting a viable experimental and test program. Broadly-based industrial participation as well as continuity of management are essential.

It will take time, planning and modest additional funding to organize the CFE and to launch the engineering program we envision. Large increases in the cost of the fusion program dedicated to engineering aspects of fusion would not be needed until about 1983–1984. At that time results from the Tokamak Fusion Test Reactor (TFTR), presently under construction at PPPL, will be available and will help confirm (or deny) the design details of the FED.

Because of the uncertainties in the prognosis for fusion and in projecting the cost of alternative energy sources, a date for a competitive commercial prototype reactor, or the number of steps needed to reach the prototype stage, cannot now be firmly specified. However, if the program we recommend is implemented and is successful, then after operation of the engineering device (in about ten years), the data should be available to predict when fusion energy could become economically competitive. A more definitive assessment of safety and environmental aspects can then also be made a part of this determination. Today, the Panel is optimistic that with progress comparable to that in the past decade, a power unit, not necessarily an economically competitive one, could be built at or shortly after the turn of the century.

As the fusion program proceeds to determine engineering feasibility, it must retain sufficient variety and flexibility to ensure that fusion's highest potential is ultimately ascertained. There remain many design options for a reactor. Excessive haste toward commercialization may lead to a demonstration of a less-than-adequate fusion reactor, delaying rather than accelerating commercial acceptability.

2. To ascertain the highest potential of magnetic fusion, a broad-based program in plasma confinement should be continued, based on the following new major elements:

(a) Following recent experimental results and favorable theoretical projections, the U.S. mirror program should proceed with the construction of the large tandem-mirror facility (MFTF–B) as a proof-of-principle experiment for open confinement systems. Its design should be sufficiently flexible to permit the incorporation of various projected configurations. Successful deployment of the MFTF–B will require extensive supporting developments in physics and in technology, at LLNL and at other institutions. The construction of the MFTF–B should be paced to accommodate results from the TMX-upgrade program.

(b) Assessment of the reactor potential of Tokamaks requires deeper understanding of many issues of plasma physics and technology which were not of immediate urgency when the present generation of machines (TFTR included) was being designed and built. Therefore, in addition to the large engineering device discussed earlier, the DOE should plan and implement a coherent comprehensive advanced

[1] The term "burning plasma" refers to conditions where the fusion energy exceeds the energy supplied to sustain the plasma. An [illegible]

Exhibit E-5, cont.

relevant studies, and the construction of some new devices. Maximum advantage should be taken of the strong international cooperative program, especially the joint program with Japan.

(c) Work on the Elmo Bumpy Torus (EBT)—a configuration which combines many of the attractive features of mirrors and Tokamaks—should be strengthened, with effort aimed at clarifying some near-term key physics questions. The EBT-P construction should wait for additional confirming results of work in progress and proposed herein, especially an exploration of the possibilities of more modest experiments. Today, the proposed EBT-P investment is too large given the existing uncertainties in the physics of the EBT configuration. If additional research points to a favorable resolution of key technical issues, we would then recommend proceeding with the construction of the EBT-P.

(d) Work on alternate concepts, that is, plasma and magnetic field configurations other than Tokamak, mirrors and the EBT, should continue commensurate with new discoveries in physics. Research on alternate concepts is essential to the full development of the plasma physics base for fusion research. However, each concept need not be pushed to, or even be expected to reach, the proof-of-principle state of plasma parameters and performance. The DOE should be highly discriminating in advancing existing alternate concepts much beyond their present scopes.

(e) The DOE should support a strong research program on fuel cycles (and their requisite containment systems) other than deuterium-tritium, since reactors based on such cycles would have major advantages in the long run.

Exhibit B-5. cont.

PART C: THE SENATE FOLLOWS SUIT

The Senate's Technical Expert

Meanwhile, on July 2, 1980, Senator Paul Tsongas had introduced similar legislation (S. 2926, the "Magnetic Fusion Engineering Act of 1980"). This bill was drafted for Senator Tsongas by Dr. Willis Smith, who worked for the Subcommittee on Engineering and Natural Resources. Dr. Smith had taken leave from his research position at Sandia Laboratories to join the Senate staff in 1974 after he was awarded an IEEE Congressional fellowship. After his one-year fellowship expired he worked for the House Science and Technology committee for 20 months and then returned to the staff of the Senate Energy and Natural Resources Committee.

Dr. Smith was in a good position to assist Senator Tsongas in the drafting of S.2926. In addition to his outstanding technical background, Will had visited all of the major fusion projects (including inertial confinement) within the last two years. He also had as background information the Foster report and the text and hearing record for H.R. 6308. In addition, Will had access to a draft of the Buchsbaum Report.

S.2926 as introduced by Senator Tsongas was less aggressive than the House bill and more in line with the Buchsbaum Report recommendations. It included a continued call for a broadly-based program, uncommitted to any particular confinement scheme. The bill also refers to a FED, a somewhat less advanced device that the ETF provided for in the House bill. Two other sections in S.2926, one establishing advisory committees for oversight and the other establishing target dates, also represented a more cautious approach than H.R. 6308.

The Senate Subcommittee on Energy Research and Development held hearings on July 28 and August 5, to get feedback on S.2926. Will Smith was present at all these hearings (he even conducted a roundtable discussion during a recess in one of them) to determine what, if any changes should be made to improve the bill. Portions of the hearing transcript are included in Exhibit C-1. This includes a discussion between Senator Tsongas and a technical expert, Dr. Stephen Dean, on the issues of the appropriate target dates and the advantages and disadvantages of the FED device vs. the ETF device; a colloquy on the same subjects between Dr. Smith and a panel of three technical experts; and two views on the appropriate form of an

advisory structure for the projects with a subsequent discussion of those points with Dr. Smith.

The Senate subcommittee considered all these recommendations; the two major factors involved in deciding what changes to make were the desire to get the bill through the Congress and the ramifications of specifying the nature of the device to be designed (FED vs. ETF).

The Politics of Fusion

The desire to push a fusion bill through before Congress adjourned for the fall elections resulted in some minor compromises in the Senate bill to make it more like the bill that had passed in the House. The sponsors of both bills wanted a single version that was agreeable to both houses, thus avoiding a conference committee to reconcile the differences. The establishment of a conference committee might delay final passage until the next Congress and neither Senator Tsongas nor Representative McCormack was willing to wait and perhaps risk rejection of the bill due to a shift in political sentiment after the 1980 elections. This, for example, was behind the compromise from the original S.2926 target date of "the year 2005" to "the turn of the century", which is more in line with the House bill.

With some amendments S.2926 was approved by the Committee on Energy and Natural Resources and reported to the Senate on September 15. On September 23, 1980, the amended S.2926 was considered by the full Senate and its language was substituted for the wording of the pending House bill H.R. 6308. So, in effect, the Senate Bill had just changed title, from S. 2926 to H.R. 6308, and passed in the Senate in that form. On the following day, after a brief discussion to clarify exactly what was happening, the bill H.R. 6308, containing the Senate wording was accepted by the House. On October 7, 1980, President Carter signed into law Public Law 96-386, the "Magnetic Fusion Engineering Act of 1980". The text of the law is included in Exhibit C-2.

STATEMENT OF DR. STEPHEN O. DEAN, PRESIDENT, FUSION POWER ASSOCIATES, GAITHERSBURG, MD.

Dr. DEAN. My name is Dr. Stephen O. Dean. I am president of Fusion Power Associates which is a nonprofit corporation dedicated to assisting in the development of fusion as a practical, environmentally acceptable energy source.

We support the general premise of S. 2926 as well as of H.R. 6308. That premise, as we see it, is that impressive scientific progress is being made in fusion research and consequently it is timely to begin to place increased emphasis during the 1980's on the practical aspects of fusion, including the engineering development of reliable and efficient technology and systems.

The members of our——

Senator TSONGAS. Could I interrupt you just for a moment? H.R. 6308 is the bill filed by Congressman McCormack and S. 2926 is the issue that we're facing here which I filed which is a synthesis of the report. You say that you support both bills?

Dr. DEAN. That's correct.

Senator TSONGAS. One Senator said to me the other day when we were discussing the candidacy of—to be head of NRC—asked him what his position was on it and he said, well, some of my friends are for him and some of my friends are against him and I support my friends. [Laughter.]

I detect a certain parallel here.

Dr. DEAN. No; I don't think so. My position is, and I think most people in the fusion community feel that both are good bills. The fusion community would be very happy to have either bill. There are differences, as you know, between the two bills but we believe that the general premise of both bills is the same mainly that in the 1980's, emphasis should be on engineering development and that in the 1990's emphasis should be on the construction of a fusion demonstration plant.

The precise dates on which these things are to happen and the precise funding profiles and the slight differences in wording in the two bills, I think are not of substance. In general, I believe that the Senate bill has more substantive policy and objective statements in it, so I think the substance of the Senate bill in general is preferable, but personally in terms of the dates involved, I believe that your bill errs on the side of being a little bit conservative and compared to what is technically possible, I believe that the House bill is perhaps a little bit ambitious given the realities of redtape in the Department and the likelihood of getting specific dollar levels in the next couple of years. I believe a compromise between the two bills is very practical and could be achieved.

Senator TSONGAS. I commend you on your way out of that question. Well done.

Exhibit C-1

Excerpts from Senate Hearings on S.2926 and H.R. 6308.

Dr. DEAN. Well, I think it's true.

Our board of directors and the names of our companies are listed in my prepared testimony. I'll just submit that for the record.

Senator TSONGAS. Let me say that is a very impressive group. How did your organization start off? How did you get going?

Dr. DEAN. Well, I became concerned about 1½ years ago that the program was not facing up sufficiently to the problem of getting industrial participation and getting ready for engineering development. Consequently, I talked to about a dozen senior people in industries that I knew were interested in fusion and asked them if they thought it wasn't time to establish some sort of an association to try to lay the groundwork for industrial participation and I had enough people who agreed with me that last fall, 10 companies joined with me in forming this association and since then we have added a number of more, so that today we have 21 total members and affiliates, including some electric utilities now.

Senator TSONGAS. Just looking at your list here, are there any major participants that are not members of your group?

Dr. DEAN. There are some that are planning to join, I believe soon, that have not yet formally gotten approvals through their own administrative processes. That includes General Electric, TRW, and Grumman, all of whom are major participants in fusion in one way or another and have not yet actually formally joined the association.

Senator TSONGAS. I would take it that you see yourself as the spokesman of the group, if you will. Are there any rival associations?

Dr. DEAN. I'm not aware of any. We believe that our goals and purposes are complementary to those of the Atomic Industrial Forum but we believe that the forum obviously has a broader charter than we have for nuclear power in general and therefore we hope by having our association solely for fusion that we will be able to give fusion more visibility as far as the industry and the engineering goes, but most of our companies also belong to the forum and we cooperate with Dr. Shapiro's committee for the forum also.

Senator TSONGAS. Would you like to read your statement before I inquire further?

Dr. DEAN. It's not necessary unless you feel that it's desirable. I can simply submit the statement for the record. I do have some additional comments.

Senator TSONGAS. We will be happy to hear them. We will submit the statement for the record.

Dr. DEAN. I have already commented on one substantive issue, I think, with respect to the dates involved in the fusion demonstration. We prefer the date of the year 2000 as a target for a demonstration date. When we're talking 20, 25 years, it seems to us that to make a distinction between the year 2000 and the year 2005 is probably too fine a distinction to be able to call at this point and I think I would feel better if one had a goal of attempting to get there by the end of the century versus a specific date like the year 2000.

With respect to the next device, the fusion engineering device or the engineering test facility, it's now 1980. I believe that we know

enough now that we could in fact technically have a device operating in 1987 as Mr. McCormack calls for if one could start immediately.

But since we have certain procedures to go through in the Government in order to get things into a budget cycle, the earliest budget cycle that it appears the Government is willing to endorse is the fiscal year 1982 budget cycle, in which case having a 1987 date is probably too tight.

I believe, though, that 1980-90 is still a little bit too lax and I would prefer some intermediate date like 1988 or 1989 for the device, especially since the Buchsbaum committee has recommended that it be a less ambitious device than was being proposed earlier by the Department.

I see no reason why such a device could not be constructed in 6 years starting in fiscal year 1982.

Senator TSONGAS. So—between 1987 and 1990—intermediary or compromise dates—by definition—1988—1989—is something that we would get to in conference. There is a difference in the bills in terms of, as you suggest, the kind of device that would be constructed.

Approach is obviously different from the Buchsbaum recommendation. My view—trying to be objective about it is that one of the dangers of taking too large a step is that you falter for a number of reasons—set the whole program back.

How would you resolve that difference in the bills?

Dr. DEAN. I believe that the more modest device proposed by the Buchsbaum committee is the appropriate device, not because I believe that technically one couldn't build a more ambitious device and make it work. I believe, however, that the cost of such a device and the magnitude of the task involved and the time it would take to build a more ambitious device would make it a more risky path that we might falter along and therefore it seems to me that it's smarter to take the somewhat less ambitious step.

I think that Mr. McCormack would very likely agree to the less ambitious machine but would probably like to still see the device built expeditiously and as quickly as possible.

Senator TSONGAS. Dr. Shapiro, I might add that the question as to how ambitious a device you would want to build is one of the questions I will be submitting to you.

I do not mean this in any negative sense, but one of the problems of this issue is the notion that it is being pushed by those who want nuclear energy at any cost, those who are perceived not by the pro and anti's but by the moderates as so zealously pronuclear as to be unable to be objective about it.

That is one of the reasons I decided to take it upon myself to try to file the bill. I am not, obviously, viewed in that respect, so I filed the bill. I would hope that the industry would be sensitive to the fact that politically this issue is going to be decided not by the converts on either side but rather than those in the middle. To the extent that the presentation can utilize reason and not somehow assume ignorance on the part of the other Members of the Congress, I think we will all be a lot better off.

There have just been many statements made by the pro and antinuclear forces over the last decade that have proven to be rhetorical, dogmatic, and ideological. I'm not accusing you of that by any means. I am just suggesting that, as we argue this issue and the differences between the two bills, credibility is going to be the major currency of trade. I would just sensitize you to that.

The Fusion Energy Foundation, for example, is doing you a lot of damage because it presents the argument in such a way that any objective third party will look at it and be repulsed. That is unfortunate because I think that, even though we end up at the same place, the reasons are invalid.

Dr. DEAN. I can't comment on behalf of the Fusion Energy Foundation. I think as some people in the community have indicated in the public press, fusion community people attempt to treat the variety of different people that come to us equally and respectfully independently of whether we agree with their political views and as you mentioned, some of the comments and positions taken by the Fusion Energy Foundation are in fact positions which we support on their merits; namely, that fusion is in fact an important element in our long-term energy policy and also we believe that high technology and technology in general in this country has got to be supported, otherwise this country will become a second-rate technological force in the world and in fact it will damage our economic competitiveness in the world and our standard of living in the long run.

colleagues in other areas of science and applied physics, nuclear physics, solid state, what have you, and materials research, that basic research in those particular program areas is also in difficult straits in terms of adequacy of funding.

Senator BRADLEY. What about your people?

Professor DAVIDSON. I find that in terms of the people working with fusion, for example, we are able to attract extremely high quality people and I suspect we will continue to be able to do so. Within the university environment, it is quite typical these days that fusion research is viewed in a very positive sense. We find that in fact many of our graduate students are approaching us to do thesis research so we can support it.

Dr. OHKAWA. The level of R. & D. is very judgmental; it is hard to identify the right level. I can only compare what is happening in the United States and what is happening in Japan and Western Europe. The contrast is very striking. For example, in Japan the R. & D., basic and applied, are strongly pushed by the Government and also in schools.

Young people are encouraged to go into basic and applied research, hard science, compared to the United States where there is more emphasis in schools, for young people, they tend to go to the soft as against the hard. Also, the industry itself and the Government expenditure on R. & D. as a function in time, Japan is increasing and there are striking contrasts.

Senator BRADLEY. Well, thank you all. I was hoping you would tell me that before Professor Gottlieb retired, you would be able to say you had a major breakthrough and that you had been able to produce a product that will solve the problem. But you have left a great legacy at Princeton and as the junior Senator from New Jersey, I am proud of you and the work that all of you are doing.

Dr. KINTNER. Senator, he has. What happened at Princeton in PLT a few years ago was the major breakthrough, at least psychologically, that have given the people at this table the confidence to come here and talk to you as they have about the future of fusion.

If that had not occurred, none of us would be in this room talking on this subject. That's Princeton and Dr. Gottlieb, he has done that.

Senator BRADLEY. Thank you.

Mr. SMITH. In the light of the fact that I doubt that we will get another Senator to return at this late hour, I think we should go back to a roundtable discussion for perhaps 30 or 45 minutes. If no Senator has returned, the hearing can be adjourned then.

Rather than going back to a synopsis of individual statements, it may be better to turn to the bill itself and talk about a few of the provisions of the bill with an eye toward trying to establish a better record as to what the advisability and desirability of certain aspects of the bill are.

I gather from the testimony that has been submitted that no one has any quarrel with the target of having engineering feasibility device by 1990 or before, given the 1981 funding levels that we are likely to achieve in appropriations.

So stating a specific date of 1987 may not be an improvement over what we have. Does anyone want to comment on that particular point?

Dr. FOWLER. I would like to make one comment. I think that in the context in which we present today, I can't really disagree with you and it does say 1990 or before. I think I would be remiss not to say that I feel that the dates in your bill and the DOE panel and documents serve two possible functions.

One is to predict and the other is to motivate; 1990 as a prediction is a pretty good number against uncertainties that might make things late and slow starting. I think in behalf of the House version of this bill, 1987 as a motivation perhaps has a little more pizzaz.

Mr. SMITH. That leaves something for conference anyway. But I think there is danger in setting unrealistic goals because people can turn around and use those against you at some point in the future and say that there is no way you will achieve the 1987 goal. They may say that you told us back in 1981 when I was first on the committee that you could achieve that goal and now you have failed miserably and it will be 1992.

You can tend to erode the aura of continued success in meeting time lines and cost goals by establishing unrealistic dates. I think we will undoubtedly have discussion about that point in the committee markup of the bill. The Senators who cosponsored this originally hopefully set a realistic goal and the bill was introduced with intent of avoiding changing it in committee markup.

Dr. GOTTLIEB. May I make one comment? I have heard statements made by the various officials that if you do not accelerate the program now, you can make up for it at a later time. I think that statement is incorrect. When you are in the hardware phase getting large objects built, it is terribly difficult to accelerate that process.

It just takes so much time to create big machines. It is the present, it is at the early phases when you can save the time. When you develop these concepts at a time when it is much less expensive. Now you can accelerate the program at much lower cost in terms of doing small things more rapidly which are a predecessor to the large objects.

Once you get into the large object, it is both difficult and extremely expensive to accelerate. That argues, I would say, for an early start to the process, as early as possible.

Mr. SMITH. We have in the bill the words "fusion engineering device" which is distinct from the House bill which talks about an engineering test facility. Part of the thought in writing the bill with those words was to decouple from the aura of what the ETF design group may propose to allow in the flexibility in deciding what the goals and objectives of this new device should be without in some sense having a connotation that we have legislated the ETF design as a requirement of the law.

Not that this necessarily should be something less than ETF, if the program people decide that these technical objectives are achievable for the project. Rather that we not connote that that is the only device that should be built.

Dr. BERRY. If I might comment regarding that, at the present time, the phase of examining engineering feasibility is one of looking at both objectives and feasibility. I don't think one should attach with letters engineering test device or test facility a continual set of objectives.

There has to be a continual matching of risk and cost of schedule and technical information. I think that is an excellent objective and even within the context of ETF one has seen objectives change and the scope change in response to both examination of the difficulties of what has to be done and in response to examining where the program really ought to be 10 years from now.

I think the general evolution of objectives is an important process and one that should not be fixed to a set of initials. What is important is the objectives and even in the context of engineering test facility and the design center, the objectives are not a fixed schedule at this point.

Dr. MENSE. May I ask a question? It is not clear to me, the distinction between ETF and FED. Apparently an attempt was made to make a distinction by the advisory panel on fusion energy. They made a statement to the effect that the objectives of ETF are not appropriate at this time and advised that you go to the FED which I take it could be—could have somewhat more modest objectives.

You were talking about difficulty in defining objectives, but apparently they make a distinction. Could you say something?

Dr. BERRY. My personal opinion regarding that process, by giving the device a new name, one makes it very clear that this is an issue to which they want attention paid and they would like their advice taken in a serious mode. They don't want one to just say yes, we understand and are listening to you and will take your advice.

By affixing a new name to the object and saying it is not what you did before, you make that point very strongly.

In my personal opinion, I think the program was heading in that direction already and was in midstream of that process. The design center is in great sense a reflection of the community itself and that includes all of the laboratories participating in it and it includes the Office of Fusion Energy as well.

All of these groups were examining the objectives and saying are these achievable or appropriate, what is the risk? We are headed in the same direction, as I indicated in the written submission. I don't think there is an abrupt need for change saying we are going in the wrong direction and we need a change, it needs an evolution and we need to take into account input from the groups that have reviewed the program, both inside the fusion effort itself and outside.

I think that process is happening now. I think the important thing that we should do is focus in a general sense, without being prejudiced by the words "fusion engineering device" or "engineering test facility" as to where we want to be 10 years from now, what level of confidence we have in obtaining those objectives, what is the technical base and what levels of ambitiousness we want to accept on that process. I think that is underway.

Dr. GOTTLIEB. Could I add one statement? You have to examine the ERAB recommendations in the light of the context in which they were made. There was a presentation to the committee of ETF, a device to be built. It still had some uncertainties in it but was a fairly specific object.

It is in light of that that you have to read ERAB's recommendations as saying you should reconsider and perhaps not build that object you were describing to us. In order to make that eminently clear, they use a different name.

Dr. MENSE. Could you say something about what objectives they would be backing down on in changing——

Dr. BERRY. I think the most specific aspect of the question had to do—I will explain myself in a few seconds, had to do with the neutron fluents that we were going to design to. There are two aspects to operating a device when you are examining engineering feasibility.

One is at which you accomplish when you first turn it on. You have proved the feasibility of doing something for a short period of time and that's a very substantial movement of the program. You have proved that the large superconducting magnets can be built and that they work and you produce a large quantity of thermonuclear power.

You had a substantial one point movement forward. There is a second set of objectives which have to do with the testing of components over long periods of time, periods of time comparable, for example, to commercial reactor operation.

My interpretation in reading the draft report is that the ambitiousness with regard to the length of period of time that we are going to operate it and the duty cycles and availability and so on that we were going to operate, one of the important things you would test in such an operation is materials, will you get a 5-year lifetime of the reactor which is what we would like to get for commercial operation.

When you look at the device and say what would be different in responding to the panel's recommendations which are still in draft form, one would not necessarily see a big change if you just looked at a cartoon. You would see a change in the supporting development, a change in the levels of reliability required for the components and you would see a change in, for example, levels of radiation damage that the superconducting coils would be required to meet.

That would be my interpretation of the panel and how they are different. It's the difference between a systems test where we would make sure that the components work and that it's possible to do it as opposed to long-term commercial prototype testing.

Dr. MENSE. It seems to me one of the problems we have is that there are so many promising approaches to fusion, and I can think of two, magnetic fusion and inertial confinement in fusion and I just wonder how far do these four programs, at least four, possibly more, how far do they have to be carried before we get an answer as to which direction we should be going and really concentrating on and can they afford to carry all four as far as they should go?

Dr. FOWLER. Let me comment on that. I can't comment for inertial fusion but I think in magnetic fusion, there has been enough time involved in the emergence of ideas. We have a pretty good outline of what that picture is about in terms of the magnetic side.

Exhibit C-1, cont.

Statement by Professor Ronald C. Davidson
Director, Plasma Fusion Center MIT

Item No. 6, finally, S. 2926 recommends the establishment of a technical panel that reports findings and recommendations on magnetic fusion to ERAB on an annual basis. I support this recommendation only if this panel functions as an oversight committee that from time to time updates general policy regarding program pace and content consistent with the accelerated development of fusion energy.

Once general policy is established for a given time frame, it should be clearly stated and understood that Government responsibility and authority for detailed program implementation and policy resides with the Office of Energy Research Associate Director for Fusion Energy and the Director of the Office of Energy Research.

One important conclusion from these recommendations is that the accelerated fusion program described in S. 2926, implemented in a manner that is most effective and in the national interest, will require significant additional resources not only for the magnetic fusion engineering center and the fusion engineering device, but for the comprehensive supporting R. & D. programs outlined earlier, as well as additional resources for the aggressive development of magnetic mirros and the most attractive alternatives.

S. 2926 estimates that a program doubling in 7 years is required for a 1990—or earlier—operating date for the fusion engineering device. In my opinion, this cost estimate may be marginal and I urge the subcommittee to reassess the cost projections for accelerated magnetic fusion energy development.

I might also add that it is my own personal feeling that the pace for developing the program in the 7 year time period, in fact, could be accelerated to a 5-year period for doubling and that would be technically merited on the basis of present accomplishments.

Statement by Dr. Melvin B. Gottlieb, Director
Plasma Physics Lab., Princeton Univ.

I should like to comment now on the requirements of the Bill in respect to the Technical Panel and Program Advisory Committees. The ERAB Technical Panel review has been extremely valuable, but an annual review process may be excessively frequent, since one review would barely be completed before the next one started.

Program Advisory Committees are very important. Most (or all) of the laboratories already have such groups, in slightly different forms, adapted to local needs. I think it would be a mistake to legislate uniform detailed structure and responsibilities for the Program Advisory Committees.

These are only minor caveats. On the whole, the Bill is an excellent one, representing a really significant national commitment to a goal of enormous importance for the world's future.

Mr. Smith. ...

The most serious concern has been raised about the technical panel of ERAB being established as a permanent entity is the annual review of the program. I think it is fair to say that the annual basis is not a well thought through number.

It could easily have been every 16 years, it was thought through no better than that. People were thinking that perhaps it should be every 3 or 4 years, that the panel is commissioned to review the program. I believe recommendation can be made to the Senators on the committee to make it more realistic in terms of reviewing the program.

Professor DAVIDSON. The Department of Energy has shown, I think, good judgment on two occasions in assembling a major high level group on the fusion program. The question I would have is why would this particular issue need to be addressed in the bill?

Is it not reasonable to assume, based on past experience, that DOE would indeed assemble such a group? Would a review appear necessary?

Mr. SMITH. That's a plausible idea. On the other hand, you might find Attila the Hun is put in charge of Department of Energy research and no information comes out for a long period of time on how to expedite the program. So there is a protection built in to have this review.

If it is done on a realistic time basis of 3 or 4 years, I do not think it is unseemly to have a program spending this much money annually reviewed on that basis. It does build in a protection that, if the program falls into unfriendly hands, it can be properly fleshed out as a topic of visibility every 3 or 4 years.

On that basis, there is very little downside and there may be some upside.

Professor DAVIDSON. The intention is not to tie the hands of the Office of Energy Research?

Mr. SMITH. No, at least that is not the intention that motivated the inclusion of this section.

Another section that has caught considerable reaction from some of the laboratories has been the one establishing a program advisory committee for the director of each lab. It has strong favorable comment from people who are not at national laboratories because they like the idea of being able to participate in the program at each lab in a direct way.

Some labs have not had a formal committee. Others have. It is not indelibly written that the committee will report a section like this, but the motivation for the section initially was to foster a sense of real involvement for competent scientists. Someone working in the field can present an idea and get a clear audience and hearing for his activities when it serves the general program, as opposed to his narrow personal ambitions to get another physical review article out of it.

Such a committee could foster the broader technical involvement of people in universities and industry who want to help achieve the ultimate goal of using fusion energy. Yet, without their support, getting a facility that costs $1.5 billion authorized and appropriated, might not be achievable either.

If you have noticed in the Department of Energy and in ERDA since the days of its inception, when a project gets above $100 million, the people who wear green eyeshades and count money carefully start looking for ways to decide that the project is no longer useful.

I think there is an inherent danger in a tight budget era in having a narrow base of support for a program that has a very large expenditure of funds coming downstream for one particular project without a constituency that is nationwide rather than housed in three or four research centers, you are liable to find that the bean counters will win every time.

This section would help foster that broader constituency. It might have glaring errors in the sense of actually harming the program and I am sure the Senators would be keenly interested in any thought to correct it or improve it in any way.

Professor DAVIDSON. I must say I personally misunderstood this section of the bill when I first read it. What seems to me to be particularly valuable is for each major fusion laboratory to have a visiting committee or advisory committee from the outside technical community which advises the laboratory director and gives him input on the impressions of the outside world of a local program.

When it comes to the general issue of developing a procedure or a committee, as you suggest, in relation to assuring that technical participation from other programs, other university programs, for example, I believe that I could now support this language in the bill.

Our own experience at MIT is that these sort of expertise on the outside that we need critically for participation in the MIT program is largely a personal matter in the sense that the scientific and engineering experts know who these people are and we are indeed very fortunate to have a number of teams doing special tasks, for example, on the arbutor project from the outside.

This, I am sure, is—in other laboratories, too. It occurs nationally is what I'm saying.

Dr. GOTTLIEB. In particular, the mandatory requirements of the laboratory following the advisory board's advice represents a real problem in terms of serving—at the same time. I think advisory

Exhibit C-1, cont.

committees are very useful, particularly when you have a choice as to whether to accept the advice.

When I say advisory committee—never really knows the details of the situation. They can be extremely useful in presenting new ways of thinking about things and new suggestions and we make very good use of our advisory committee in that sense.

But actual control and responsibility should not be in the hands of an advisory committee.

Dr. Fowler. I would like to make some comments about this; Will and I have had a number of discussions already and I have presented additional remarks for the record. I am just elaborating some of my feelings about it.

I think the two most important points about this section, section 8 of the bill as now written, are the points in section 8(2) (b) and (c) concerning composition of the committee that make it in a sense self-perpetuating and the other is the charter to the committee which was section 8(c) as I recall which had very much by intent the kind of flavor Will was stating of involvement of a wider community of interest in the activities of the laboratory.

The first point concerning the groups choosing its own members, I don't know exactly what the purpose was. But it would appear to me to be one of providing some insulation so the group could in fact have a bit more authority to execute the kind of functions laid out in section 8(c).

I saw this as parallel, one, to give the committee independence, and second, to charter it toward purposes which are really quite different from the kind of committee Ron Davidson was talking about or the advisory committees as they presently exist, I think, uniformly throughout the community where advisory committees are used to bring in other points of view, especially on big issues and in the specific technical areas the advisory committees as they now function, primarily technical monitors in the sense of advising whether the—activities meet technical standards.

The bill sees a committee with a quite different purpose. I think the idea that the committee is not determined by the laboratory removes it from being an advisory committee to the laboratory. It would almost be preferable for the purpose of monitoring the laboratory by someone else, that at least someone else name the committee.

A committee that only names itself, I feel is one that is responsible to no one or at best in seeking an authoritative group that it is responsible to, assuming it is responsible to you. I don't think that was your intent. I would particularly suggest that that wording be deleted.

As to the users group character in the charter, section 8(c), I'm rather concerned about that. My reasons are twofold: one, there is certainly in our area processes in place that were expressly put together by us and motivated by the need for a wider technical input and to some degree, as you put it, constituency, people who would know enough about us that they could comment one way or another about our activities, someone who would be knowledgeable about the mirror program.

Exhibit C-1, cont.

Public Law 96-386
96th Congress

An Act

To provide for an accelerated program of research and development of magnetic fusion energy technologies leading to the construction and successful operation of a magnetic fusion demonstration plant in the United States before the end of the twentieth century to be carried out by the Department of Energy.

Oct. 7, 1980
[H.R. 6308]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Magnetic Fusion Energy Engineering Act of 1980".

Magnetic Fusion Energy Engineering Act of 1980.
42 USC 9301 note.

FINDINGS AND POLICY

42 USC 9301.

SEC. 2. (a) The Congress hereby finds that—

(1) the United States must formulate an energy policy designed to meet an impending worldwide shortage of many exhaustible, conventional energy resources in the next few decades;

(2) the energy policy of the United States must be designed to ensure that energy technologies using essentially inexhaustible resources are commercially available at a time prior to serious depletion of conventional resources;

(3) fusion energy is one of the few known energy sources which are essentially inexhaustible, and thus constitutes a long-term energy option;

(4) major progress in all aspects of magnetic fusion energy technology during the past decade instills confidence that power production from fusion energy systems is achievable;

(5) the United States must aggressively pursue research and development programs in magnetic fusion designed to foster advanced concepts and advanced technology and to develop efficient, reliable components and subsystems;

(6) to ensure the timely commercialization of magnetic fusion energy systems, the United States must demonstrate at an early date the engineering feasibility of magnetic fusion energy systems;

(7) progress in magnetic fusion energy systems is currently limited by the funds made available rather than technical barriers;

(8) it is a proper role for the Federal Government to accelerate research, development, and demonstration programs in magnetic fusion energy technologies; and

(9) acceleration of the current magnetic fusion program will require a doubling within seven years of the present funding level without consideration of inflation and a 25 per centum increase in funding each of fiscal years 1982 and 1983.

(b) It is therefore declared to be the policy of the United States and the purpose of this Act to accelerate the national effort in research, development, and demonstration activities related to magnetic fusion energy systems. Further, it is declared to be the policy of the United States and the purpose of this Act that the objectives of such program shall be—

(1) to promote an orderly transition from the current research and development program through commercial development;

(2) to establish a national goal of demonstrating the engineering feasibility of magnetic fusion by the early 1990's;

(3) to achieve at the earliest practicable time, but not later than the year 1990, operation of a magnetic fusion engineering device based on the best available confinement concept;

(4) to establish as a national goal the operation of a magnetic fusion demonstration plant at the turn of the twenty-first century;

(5) to foster cooperation in magnetic fusion research and development among government, universities, industry, and national laboratories;

(6) to promote the broad participation of domestic industry in the national magnetic fusion program;

(7) to continue international cooperation in magnetic fusion research for the benefit of all nations;

(8) to promote greater public understanding of magnetic fusion; and

(9) to maintain the United States as the world leader in magnetic fusion.

DEFINITIONS

42 USC 9302.

SEC. 3. For the purposes of this Act—

(1) "fusion" means a process whereby two light nuclei, such as deuterium and tritium, collide at high velocity, forming a compound nucleus, which subsequently separates into constituents which are different from the original colliding nuclei, and which carry away the accompanying energy release;

(2) "magnetic fusion" means the use of magnetic fields to confine a very hot, fully ionized gas of light nuclei, so that the fusion process can occur;

(3) "energy system" means a facility designed to utilize energy released in the magnetic fusion process for the generation of electricity and the production of hydrogen or other fuels;

(4) "fusion engineering device" means a magnetic fusion facility which achieves at least a burning plasma and serves to test components for engineering purposes;

(5) "demonstration plant" means a prototype energy system which is of sufficient size to provide safety, environmental reliability, availability, and ready engineering extrapolation of all components to commercial size but which system need not be economically competitive with then alternative energy sources; and

(6) "Secretary" means Secretary of Energy.

PROGRAM ACTIVITIES

42 USC 9303.

SEC. 4. (a) The Secretary shall initiate activities or accelerate existing activities in research areas in which the lack of knowledge limits magnetic fusion energy systems in order to ensure the achievement of the purposes of this Act.

Plasma confinement research.

(b)(1) The Secretary shall maintain an aggressive plasma confinement research program on the current lead concept to provide a full measure of support for the design, construction, and operation of the fusion engineering devices.

ECL-258C

Exhibit C-2, Public Law 96-386

(2) The Secretary shall maintain a broadly based research program on alternate confinement concepts and on advanced fuels at a sufficient level of funding to achieve optimal design of each successive magnetic fusion facility using the then best available confinement and fuel concept.

(3) The Secretary shall ensure that research on properties of materials likely to be required for the construction of fusion engineering devices is adequate to provide timely information for the design of such devices.

Fusion engineering device designs.

(c)(1) The Secretary shall initiate design activities on a fusion engineering device using the best available confinement concept to ensure operation of such a device at the earliest practicable time, but not later than the year 1990.

(2) The Secretary shall develop and test the adequacy of the engineering design of components to be utilized in the fusion engineering device.

(d) The Secretary shall initiate at the earliest practical time each activity which he deems necessary to achieve the national goal for operation of a demonstration plant at the turn of the twenty-first century.

Magnetic fusion energy systems, assessment factors.

(e) The Secretary shall continue efforts to assess factors which will determine the commercial introduction of magnetic fusion energy systems including, but not limited to—

(1) projected costs relative to other alternative energy sources;

(2) projected growth rates in energy demand;

(3) safety-related design limitations;

(4) environmental impacts; and

(5) limitations on the availability of strategic elements, such as helium, lithium, and special metals.

COMPREHENSIVE PROGRAM MANAGEMENT PLAN

42 USC 9304.

SEC. 5. (a) The Secretary shall prepare a comprehensive program management plan for the conduct of the research, development, and demonstration activities under this Act. Such plan shall include at a minimum—

(1) a presentation of the program strategy which will be used to achieve the purposes of this Act;

(2) a five-year program implementation schedule, including identification of detailed milestone goals, with associated budget and program resources requirements;

(3) risk assessments;

(4) supporting research and development needed to solve problems which may inhibit or limit development of magnetic fusion energy systems; and

(5) an analysis of institutional, environmental, and economic considerations which are limiting the national magnetic fusion program.

Submittal to congressional committees.

(b) The Secretary shall transmit the comprehensive program management plan to the Committee on Science and Technology of the House of Representatives and the Committee on Energy and Natural Resources of the Senate not later than January 1, 1982.

MAGNETIC FUSION ENGINEERING CENTER

42 USC 9305.

SEC. 6. (a) The Secretary shall develop a plan for the creation of a national magnetic fusion engineering center for the purpose of accelerating fusion technology development via the concentration

and coordination of major magnetic fusion engineering devices and associated activities at such a national center.

Plan development, factors.

(b) In developing the plan, the Secretary shall include relevant factors including, but not limited to—

(1) means of saving cost and time through the establishment of the national center relative to the cost and schedule currently projected for the program;

(2) means of providing common facilities to be shared by many magnetic fusion concepts;

(3) assessment of the environmental and safety-related aspects of the national center;

(4) provisions for international cooperation in magnetic fusion activities at the national center;

(5) provision of access to facilities for the broader technical involvement of domestic industry and universities in the magnetic fusion energy program;

(6) siting criteria for the national center including a list of potential sites;

(7) the advisability of establishing such a center considering all factors, including the alternative means and associated costs of pursuing such technology; and

(8) changes in the management structure of the magnetic fusion program to allow more effective direction of activities related to the national center.

Report to congressional committees.

(c) The Secretary shall submit not later than July 1, 1981, a report to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources characterizing the plan and setting forth the steps necessary for implementation of the plan, including any steps already implemented.

TECHNICAL PANEL ON MAGNETIC FUSION

42 USC 9306.

SEC. 7. (a) A technical panel on magnetic fusion of the Energy Research Advisory Board shall be established to review the conduct of the national magnetic fusion energy program.

Membership.

(b)(1) The technical panel shall be comprised of such representatives from domestic industry, universities, government laboratories, and other scientific and technical organizations as the Chairman of the Energy Research Advisory Board deems appropriate based on his assessment of the technical qualifications of each such representative.

(2) Members of the technical panel need not be members of the full Energy Research Advisory Board.

(c) The activities of the technical panel shall be in compliance with any laws and regulations guiding the activities of technical and fact-finding groups reporting to the Energy Research Advisory Board.

Review.

(d) The technical panel shall review and may make recommendations on the following items, among others:

Ante, p. 1541.

(1) the preparation of the five-year program plan prepared pursuant to section 5;

(2) the type of future facilities needed to meet the goals of this Act along with their projected completion dates;

(3) the adequacy of participation by universities and industry in the program;

(4) the adequacy of international cooperation in magnetic fusion and any problems associated therewith; and

(5) institutional, environmental, and economic factors limiting, or prospectively limiting, efforts to achieve commercial application of magnetic fusion energy systems.

Written report.

(e) The technical board shall submit to the Energy Research Advisory Board on at least a triennial basis a written report of its findings and recommendations with regard to the magnetic fusion program.

Report to Secretary.

(f) After consideration of the technical panel report, the Energy Research Advisory Board shall submit such report, together with any comments such Board deems appropriate, to the Secretary.

PROGRAM ADVISORY COMMITTEES

42 USC 9307.

SEC. 8. The Secretary may direct the director of each laboratory or installation at which a major magnetic fusion facility is operated for, or funded primarily by, the Federal Government to establish, for the sole purpose of providing advice to such director, a program advisory committee composed of persons with expertise in magnetic fusion from such domestic industry, universities, government laboratories, and other scientific and technical organizations as such director deems appropriate.

INTERNATIONAL COOPERATION

42 USC 9308.

SEC. 9. (a)(1) The Secretary in consultation with the Secretary of State shall actively seek to enter into or to strengthen existing international cooperative agreements in magnetic fusion research and development activities of mutual benefit to all parties.

(2) The Secretary shall seek to achieve equitable exchange of information, data, scientific personnel, and other considerations in the conduct of cooperative efforts with technologically advanced nations.

Magnetic fusion, examination and exploration.

(b)(1) The Secretary shall examine the potential impacts on the national magnetic fusion program of United States participation in an international effort to construct fusion engineering devices.

(2) The Secretary shall explore, to the extent feasible, the prospects for joint financial participation by other nations with the United States in the construction of a fusion engineering device.

Results, transmittal to congressional committees.

(3) Within two years of the enactment of this Act the Secretary shall transmit to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources the results of such examinations and explorations with his recommendations for construction of a national or international fusion engineering device: *Provided, however,* That such examinations and explorations shall not have the effect of delaying design activities related to a national fusion engineering device.

TECHNICAL MANPOWER REQUIREMENTS

42 USC 9309.

SEC. 10. (a) The Secretary shall assess the adequacy of the projected United States supply of manpower in the engineering and scientific disciplines required to achieve the purposes of this Act taking cognizance of the other demands likely to be placed on such manpower supply.

Report to President and Congress.

(b) The Secretary shall within one year of the date of enactment of this Act submit a report to the President and to the Congress setting forth his assessment along with his recommendations regarding the need for increased support for education in such engineering and scientific disciplines.

INFORMATION DISSEMINATION

42 USC 9310.

SEC. 11. (a) The Secretary shall take all necessary steps to assure that technical information relevant to the status and progress of the national magnetic fusion program is made readily available to interested persons in domestic industry and universities in the United States: *Provided, however,* That upon a showing to the Secretary by any person that any information or portion thereof provided to the Secretary directly or indirectly from such person would, if made public, divulge (1) trade secrets or (2) other proprietary information of such person, the Secretary shall not disclose such information and disclosure thereof shall be punishable under section 1905 of title 18, United States Code.

(b) The Secretary shall maintain an aggressive program in the United States for the provision of public information and educational materials to promote widespread knowledge of magnetic fusion among educational, community, business, environmental, labor, and governmental entities and the public at large.

REPORTS

Submittal to Congress.
42 USC 9311.
42 USC 7321.

SEC. 12. As a separate part of the annual report submitted pursuant to section 801 of the Department of Energy Organization Act (Public Law 95-91), the Secretary shall submit to Congress an annual report of activities pursuant to this Act. Such report shall include—

(a) modifications to the comprehensive program management plan for implementing this Act;

(b) an evaluation of the status of national magnetic fusion energy program in the United States;

(c) a summary of the findings and recommendations of any report of the Energy Research Advisory Board on magnetic fusion;

(d) an analysis of the progress made in commercializing magnetic fusion technology; and

(e) suggestions for improvements in the national magnetic fusion program, including recommendations for legislation.

AUTHORIZATION OF APPROPRIATIONS

42 USC 9312.

SEC. 13. (a) There is hereby authorized to be appropriated to the Secretary, for the fiscal year ending September 30, 1981, such sums as are provided in the annual authorization Act pursuant to section 660 of Public Law 95-91.

42 USC 7270.
Contract.

(b) In carrying out the provisions of this Act, the Secretary is authorized to enter into contracts only to such extent or in such amounts as may be provided in advance in appropriations Acts.

Approved October 7, 1980.

LEGISLATIVE HISTORY:

HOUSE REPORT No. 96-1096 (Comm. on Science and Technology).
SENATE REPORT No. 96-942 accompanying S. 2926 (Comm. on Energy and Natural Resources).
CONGRESSIONAL RECORD, Vol. 126 (1980):
Aug. 25, considered and passed House.
Sept. 23, S. 2926 considered and passed Senate; passage vitated and H.R. 6308, amended, passed in lieu.
Sept. 24, House concurred in Senate amendments.
WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS, Vol. 16, No. 44:
Oct. 7, Presidential statement.

ECL-258N

Educating Prospective Engineers for Public Policy

INSTRUCTOR'S GUIDE FOR A CASE ON

THE MAGNETIC FUSION ENERGY ENGINEERING ACT OF 1980

by

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Prepared as part of the 1981 Washington Internship for Students of Engineering (WISE) Program under the supervision of Dr. Paul Craig[2], 1981 WISE Faculty-Member-in-Residence. Modified and edited by Barry Hyman[3]. This work was supported by NSF Grant SED 7918984. All opinions presented are those of the authors and do not in any way represent those of NSF, the authors' institution, or other individuals or institutions referred to in the text.

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This is one of a series of cases written to provide students with an opportunity to see how public policy decisions affect the engineering design process. This case focuses on the development of national policy goals for a major energy resource--fusion--and how that affects the scientific and engineering targets.

There are several modes of using this case; much is deliberately left to the instructor's choice. This increases the flexibility of the case use and allows its use in more than one type of course. There is more than enough technical material describing various technologies and devices that the case can be used as a prime resource in an advanced technical course for a survey of the fusion state of the art. Nonetheless, no matter what the instructor may choose to do with this case, the student who has gone through it should have some feel for the problems of defining and managing a major national research effort and the role of the technical community in the political process. In fact, the importance of political considerations to attainment of national scientific and engineering goals is probably the central lesson of this case. The student, as he or she reads through the case, will be struck by the constant intrusion of political considerations into the fusion effort.

The questions that follow are designed to suggest possible assignments, projects, exam questions and topics for various aspects of this case.

INTRODUCTION

1. Describe several of the other possible fusion reactions and compare their characteristics with those of the D-T reaction.

2. Compare the tokamaks, mirrors and the "bumpy torus" hybrid as fusion reactors. Write a memo explaining to a Congressperson which one should be pursued and why.

PART A: A BRIEF HISTORY OF THE FUSION PROGRAM

1. Some would argue that we would be much further along in the fusion programs if they had been the responsibility of engineers rather than scientists. The idea is that engineers <u>solve</u> problems, scientists <u>study</u> them. Do you agree with this statement? Do your physicist friends agree with it? How is this issue related to the "psychological reason" for choosing the D-T reaction?

2. Which is likely to be the "better" management style for the national fusion program---decentralized in the national labs or centralized in Washington? What criteria would you use to evaluate "better" and might they change from an early program to a more mature one?

3. Dr. Hirsch allowed several factors to influence the goals he established. How important were the political factors? Are the scientific reasons for selecting the D-T reaction good ones?

PART B: MIKE MCCORMACK TO THE RESCUE

1. Representative McCormack established an advisory panel to his subcommittee. What considerations do you think he used in selecting its members? If you were asked to serve, because of your technical expertise, and you had no prior strong feelings on the issues, would you feel that your role should be that of an objective analyst or that of an advocate for a particular viewpoint?

2. Compare the membership of Congressman McCormack's advisory panel to that of the "Buchsbaum" panel established by DOE. Does the difference in membership account for their different conclusions about proceeding with the ETF device?

3. In the eyes of some participants in the debate, the differences between the FED and the ETF were not significant; to others the differences were never made clear. Study the Büchsbaum report and other background materials and prepare a short briefing paper for your congressman explaining these differences.

PART C: THE SENATE FOLLOWS SUIT

1. Describe all the different ways in which technically trained individuals contributed to the passage of the legislation. Could you see yourself playing any, or all, of those roles?

2. Analyze H.R. 6308 as introduced and as modified by committee, and compare it to S.2926 and P.L. 96-386, to see what happened to the proposed level of funding for this program as the legislation progressed. Follow up to see whether in fact this law has resulted in any additional money being spent for fusion programs.

3. The emphasis on activities in the House of Representatives is on the activites of representative McCormack. The Senate activities focus on a staff member, Dr. Smith.

Is this typical of the difference between the House and Senate? Why might this be the case? What difference is this likely to make to the technical understanding evidenced in legislative activities?

4. Read the Congressional Record and analyze the "debate" which actually occured on the House and Senate floors prior to passage. Why do you think there was no vocal opposition to the legislation? Without such opposition, what is the purpose of holding a "debate"?